Volume 10 APRIL 8, 1935 Number 2, Part 1

BUREAU OF STANDARDS
APR 11 1935
LIBRARY

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM OF THE

WASHINGTON MEETING

AT THE

BUREAU OF STANDARDS

AND THE

NATIONAL ACADEMY OF SCIENCES

April 25–27, 1935

PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY
SEVEN ISSUES EACH YEAR

The American Physical Society

OFFICERS OF THE SOCIETY FOR 1935

President	R. W. Wood	The Johns Hopkins University
Vice President	F. K. Richtmyer	Cornell University
Secretary	W. L. Severinghaus	Columbia University
Treasurer	G. B. Pegram	Columbia University
Editor	John T. Tate	University of Minnesota
Local Secretary for the Pacific Coast	L. B. Loeb	University of California

COUNCIL

The President, Vice President, Secretary, Treasurer, Managing Editor, the three Past Presidents most recently retired from office, eight elected members and all Past Presidents first elected to the office of President prior to December 1932 constitute the Council which shall have general charge of the affairs of the Society.

Past Presidents: Carl Barus, E. L. Nichols, Henry Crew, W. F. Magie, Ernest Merritt, R. A. Millikan, J. S. Ames, Theodore Lyman, C. E. Mendenhall, D. C. Miller, K. T. Compton, H. G. Gale, W. F. G. Swann, Paul D. Foote and A. H. Compton.

Elected Members: F. L. Mohler, J. H. VanVleck, L. O. Grondahl, E. C. Kemble, E. O. Lawrence, F. K. Richtmyer, G. Breit and K. K. Darrow.

BULLETIN

of the

AMERICAN PHYSICAL SOCIETY

Published seven times per year

Subscription price: $5.00 per year

Single copies: $1.00 each

The Bulletin of the American Physical Society is published seven times a year during the months of February, April, June (2 issues), November (2 issues), and December at Prince and Lemon Streets, Lancaster, Pa.

Address correspondence to Prince and Lemon Streets, Lancaster, Pa., or to Secretary W. L. Severinghaus, Columbia University, New York, N. Y.

Entered at the post office at Lancaster, Pa., as second class matter.

Acceptance for mailing at a special rate of postage provided for in the Act of October 3, 1917, embodied in paragraph 4, Section 412, P. L. & R., authorized April 28, 1928.

APRIL 8, 1935 Vol. 10, No. 2, Part 1

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

WASHINGTON MEETING, APRIL 25–27, 1935

THE 198th regular meeting of the American Physical Society will be held in Washington, D. C., at the Bureau of Standards on Thursday and Friday, April 25 and 26, 1935, and at the National Academy of Sciences, B and 21st Streets, on Saturday, April 27, 1935. The first session will be at 10:00 o'clock on Thursday morning.

There will be sessions in the East Building, the Industrial Building, and the Chemistry Building at the Bureau of Standards, and in the Auditorium and the Lecture Hall of the National Academy of Sciences. The schedule of papers is given in the Calendar below.

Dinner. On Friday evening at 7:00 o'clock there will be a dinner for the members and their friends at the Raleigh Hotel. The price for the dinner will be $2.00. Tickets must be purchased at the registration desk at the Bureau of Standards.

Luncheon. On Thursday and Friday luncheon will be served in the cafeteria in the Industrial Building, Bureau of Standards. There will be cafeteria service.

Headquarters. Headquarters will be at the Raleigh Hotel, Pennsylvania Avenue and 12th Street. There will be a flat rate to those attending the meeting of $3.50 for single rooms and $5.00 for double rooms. Advance reservations are urged as hotels will be crowded. Please write directly to the hotel for accommodations.

Railroad Rates. A reduction in railroad fares to "one and one-third fare on the Identification Certificate Plan" will apply for members and their immediate families attending the meeting of the National Academy of Sciences or the American Physical Society in Washington. *An Identification Certificate*, printed with the member's name, was sent to each member with the notice of this meeting. Only one is needed for each member and his family. It will be necessary for each member, when purchasing round-trip tickets, to present and surrender the Identification Certificate issued in his name on account of this meeting and to indicate to the ticket agent which ticket is desired—namely (1) one and one-third fare for round trip, good via same route in both directions, final return limit 30 days in addition to date of sale; or (2) one and one-third fare for round trip, going via any authorized route and returning via another authorized route, final return limit 30 days in addition to date of sale. Concerning dates of sale and final return limit of tickets consult your local ticket agent.

Summer Meeting at Los Angeles. The summer meeting on the Pacific Coast will be held in affiliation with the Pacific Division of the American Association for the Advancement of Science at Los Angeles, California, during the week of June 24–28, 1935. It is planned to hold one session at the California Institute of Technology at Pasadena if possible.

Summer Meeting at Minneapolis. The summer meeting in the east will be held at Minneapolis, Minnesota, by invitation from the Department of Physics of the University of Minnesota. Definite arrangements for this meeting have not yet been

made but there will be an interesting scientific program as well as outside entertainment particularly arranged for getting acquainted.

General Rules Relating to Papers

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. (A paper presented by two or more authors is assigned to the first named author.) Papers received after the program has been printed will be placed in the supplementary program.

All supplementary papers will be grouped according to subject matter and will be called for at their appropriate sessions only, these sessions to be designated on the program. The presiding officer may assign a reduced time to these papers or may in his discretion call for them to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts will be published in an early number of the *Physical Review*. Authors should send corrections to the Editorial Secretary, The American Institute of Physics, Incorporated, 11 East 38th Street, New York, N. Y.

Other meetings for the current season are as follows:

199. June 24–28, 1935. Los Angeles, California.
200. June 21–22, 1935. Minneapolis, Minnesota.
201. November 29–30, 1935. Baltimore, Maryland.
202. December, 1935. Pacific Coast Section.
203. December, 1935. St. Louis, Missouri. Annual Meeting.

Harold W. Webb, *Acting Secretary*,
Columbia University, New York, N. Y.

April 8, 1935.

CALENDAR

Thursday morning

10:00 o'clock: B of S East Building: Papers 1–8 and 131.

10:00 o'clock: B of S Industrial Building: Papers 9–15.

10:00 o'clock: B of S Chemistry Building: Papers 16–23.

Thursday afternoon

2:00 o'clock: B of S East Building: Papers 24–31.

2:00 o'clock: B of S Industrial Building: Papers 32–39.

2:00 o'clock: B of S Chemistry Building: Papers 40–48.

4:00 o'clock: B of S South Building: Room 300: Council Meeting.

Friday morning

10:00 o'clock: B of S East Building: Papers 49–58.

10:00 o'clock: B of S Industrial Building: Papers 59–66.

10:00 o'clock: B of S Chemistry Building: Papers 67–74.

Friday afternoon

2:00 o'clock: B of S East Building: Papers 75–83 and 132.

2:00 o'clock: B of S Industrial Building: Papers 84–90 and 133.

2:00 o'clock: B of S Chemistry Building: Papers 91–98.

Friday evening

7:00 o'clock: Raleigh Hotel: Dinner.

Saturday morning

10:00 o'clock: N A of S Auditorium: Papers 99–106 and 134.

10:00 o'clock: N A of S Lecture Hall: Papers 107–115.

Saturday afternoon

2:00 o'clock: N A of S Auditorium: Papers 116–122.

2:00 o'clock: N A of S Lecture Hall: Papers 123–130.

PROGRAM

THURSDAY MORNING AT 10:00 O'CLOCK

Bureau of Standards

East Building, Lecture Room

1. Variation of Small-ion Production Near the Earth's Surface. A. G. MCNISH AND G. R. WAIT, *Carnegie Institution of Washington, Department of Terrestrial Magnetism.*—Measurements of small-ion production in a thin-walled, closed vessel during 1933 and 1934, at Washington, D. C., demonstrate the existence of a regular diurnal variation in the production-rate. A maximum occurs around sunrise and a minimum shortly before sunset, on fair-weather days. The form of the variation is similar to the inverse of the daily temperature-curve and is therefore interpreted as due to a diminution of the radium-emanation content, in the lower region of the atmosphere, through scattering by convection currents. Contrary to popular beliefs there is no apparent connection between the rate of small-ion production and changes in the barometric pressure. In addition to the regular variations there are saltatory variations, ion-production being unusually high or unusually low for one or more hours at a time, which have not been associated with any meteorological phenomenon. These saltatory variations are distinct from the increase in ion-production accompanying thunderstorms previously reported.[1]

[1] Mon. Weath. Rev. **62**, 1–4 (1934).

2. The Distinction Between Langevin Ions and Dust-Particles in the Atmosphere. G. R. WAIT, *Carnegie Institution of Washington, Department of Terrestrial Magnetism.*—It is commonly believed that the Langevin ions (mobility about 1/3000 cm per sec. per volt per cm) of the atmosphere are electrically charged dust-particles. The fact that these ions do not exist in a gas from which all dust has been filtered has contributed to this belief. Two sets of experimental results are in agreement in showing that the Langevin ions of the atmosphere are not dust-particles. (1) These ions are condensation-nuclei, whereas ordinary dust-particles do not act as centers for condensation as has been shown by previous experiments. (2) These ions diminish greatly in number during times of dust-storms. The diminution in number is interpreted to mean that the dust-particles, through combination with the condensation-nuclei, remove them from the air. Through the process of filtering, the condensation-nuclei are removed from the air as well as the dust-particles, thus accounting for the absence of Langevin ions in filtered air.

3. The Annual and Diurnal Variations of Ions in Urban Communities. A. P. GAGGE, *John B. Pierce Foundation and Yale University.*—The results of daily ion counts at 9 A.M. and 24-hour counts taken once a month are given for the year from February, 1934, to February, 1935, at a station located in the center of New Haven City. The counts for both positive and negative ions are presented for four threshold mobilities, *viz.*: 0.05, 0.017, 0.0017, and 0.0006 cm per second; volt per cm. The number of ions were determined by hand on a counter of the Zeleny type, made at Frankfurt, Germany. Analysis of the mobility spectrum shows there to be only two finite mobility values, the usual small ions and the large, Langevin ions. The mobilities for the latter ions were found to be 0.0007 for the positive and 0.0005 for the negative. The number of positive ions of the small-ion group showed a rise for the summer months over that of the winter months. On the other hand, the number of negative ions in the small-ion group decreased during the summer months. In the large-ion group there is a minimum for both signs in July and a maximum in January. The diurnal variation for the ions of both signs of the small-ion group shows a single small maximum at 4 P.M. (E.S.T.) and a minimum at 3 A.M., for the year around. For the large-ions the diurnal variation has a maximum at 7 A.M. and at 7 P.M., for the winter months, while the second maximum becomes less distinct for the summer months.

4. The Electricity of Rain and Thunderstorms. ROSS GUNN, *Naval Research Laboratory, Washington, D. C.*—Rain.—It is shown that the unusually diverse electrical properties of rain may be correlated by assuming that each elementary water droplet and the surrounding ionized water vapor constitute a concentration cell of some 60 millivolts potential difference. The electrical charge on the droplet is therefore proportional to its radius and can be shown to be positive if the drop is evaporating and negative if it is condensing. The elementary droplets grow by association into large drops and build up charges of the order of 1/50 e.s.u. which discharge by conduction in a time of the order of 10^3 seconds. The calculated values are in excellent agreement with those observed. Thunderstorms.—It is shown that, in the presence of a rapidly rising current of air and the formation of raindrops greater than a critical size, separation of charge takes place. The ions (usually positive) are swept to great heights while the rain (usually negative initially) falls. Both charge distributions discharge, but at different rates, leaving a usually negative free charge in the rain formation zone which, in turn, induces a usually positive charge on the earth. The electrical distributions in a typical thunderstorm are quantitatively calculated from physical data and excellent agreement is obtained with observation in regard to the potential difference, electric field, electric moment, charging current, recovery time and the charges precipitated on rain. The maintenance of the earth's charge may be attributed to precipitation by rain under

special conditions or possibly to systematic convection induced either by great natural barriers or by heat released in special regions by volcanic action.

5. A Mobile Radio Research Laboratory. H. SELVIDGE AND HARRY ROWE MIMNO, *Harvard University.*—A mobile research unit, recently constructed by the Cruft Laboratory, extends the scope of present fundamental research on ultra-high-frequency radio propagation, ground wave propagation, scattering and ionosphere refraction. All experimental apparatus is mounted on relay racks, which form an integral part of a special steel body built on a Packard chassis. Partial heat and sound insulation and electrical shielding are provided. All equipment can be operated either from internal power sources in the truck or from external alternating current. The apparatus initially installed includes: (a) a novel ultra-high-frequency receiver operating on three channels between 1 and 6 meters; (b) a superheterodyne receiver covering the range from 10 to 550 meters; (c) cathode ray monitor equipment; (d) a low-power 5-meter transmitter; (e) a 200-watt crystal-controlled transmitter, operating on any of eight channels between 17 and 85 meters. Either transmitter can be operated with code, voice or pulse modulation. The main transmitter is also designed so that it can deliver a two-phase radiofrequency output for use in new Kennelly-Heaviside layer polarization experiments. Additional equipment can be added or substituted quickly. The new power unit will supplement two trailers which have been employed previously.

6. Recording of Ionosphere Echoes at Non-Vertical Incidence. PAUL B. KING, JR. AND HARRY ROWE MIMNO, *Harvard University.*—Continuous recording apparatus, used in tracing rapid changes in the ionosphere, must maintain exact synchronism with a modulating device at the associated transmitting station. In previous experiments synchronization has been obtained by operating 60-cycle motors on a common power network. The transmitters and receivers have usually been located in the same metropolitan area and the waves returned to earth after reflection at practically normal incidence. By simultaneous measurements at a distance it should be possible to secure additional information regarding vertical distribution of ionization, horizontal extent of ionic clouds, directional effects produced by the earth's field and the extent of ground-wave propagation under various soil conditions. Self-synchronizing sweep circuits have been tested but for best results the synchronizing device should be independent of the echo pattern which is being observed. In a trial installation we have used unattended motor-driven automatic apparatus, mounted in an automobile trailer, at a point 40 miles from the Cruft Laboratory. To extend the range beyond the reliable limit of the 60-cycle power network we have recently constructed a portable crystal-controlled thyratron inverter which maintains synchronism with the absolute frequency standard at the laboratory. The frequency drift has been reduced below 0.0001 percent per hour.

7. The Exact Measurement of Electron Tube Coefficients. ROGER W. HICKMAN AND FREDERICK V. HUNT, *Harvard University.*—The analysis of the conventional bridge circuits (Chaffee, *Thermionic Vacuum Tubes*) for the measurement of electron tube coefficients has been extended to include the effect of grid current and tube and battery capacitances. It has been found that the addition of an auxiliary capacitance bridge to the usual circuits permits annulment of the quadrature component of voltage introduced into the detector circuit by the tube capacitances. In every case in which one or more of the tube capacitances form one arm of the auxiliary bridge the conditions of balance show the expression for the tube coefficient to be independent of the capacitances of the auxiliary bridge. If all the tube capacitances are considered it appears that a single balancing condenser in the auxiliary bridge will always suffice to give an exact null balance, although the expression for the tube coefficient may contain a correction factor, usually negligible, involving the capacitances. This capacitance balancing method has been applied to circuits suitable for measuring both positive and negative values of the plate and grid coefficients and the exact expressions for the coefficients are given under the general condition that electron current flows to both grid and plate.

8. A New Type Radio Transmitter for Short Waves.[1] RONOLD KING, *Lafayette College.*—The directional properties of the loop type antenna are incorporated in a new form of radiator of electromagnetic waves. The device combines in a single compact unit a multi-oscillator and a directional antenna system. The circuit, construction, and properties of an ultra-short wave transmitter of this type operating at a carrier frequency of 170 megacycles are described, and a working model is displayed. The condition for oscillation and the frequency equation are briefly discussed; the formula for the radiation resistance is given. The solution of the equations for the electromagnetic field is outlined for the wave zone; it is shown that a good approximation of the field is that of the magnetic dipole. Several modifications in the form of the device and their effect on its characteristics are considered, together with possible applications in the field of short wave radio transmission.

[1] The mathematical treatment has been sent to the Philosophical Magazine of London under the title, *A Loop Transmitter.*

THURSDAY MORNING AT 10:00 O'CLOCK

Bureau of Standards

Industrial Building, Room 301

9. The Spectrum of Carbon Deuteride. ANDREW MCKELLAR AND CHARLES A. BRADLEY, JR., National Research Fellows, *Massachusetts Institute of Technology.*—Bands due to the CD molecule with heads at λ4307 and λ3865 have been photographed using a 21-foot grating and also in the first order of the Institute's 35-foot 30,000 lines per inch grating. They were obtained both by means of a hollow cathode discharge in C_2D_2 and by burning C_2D_2 in an excess of oxygen. The bands correspond to the $^2\Delta$, $^2\Pi$CH band with head at λ4315 and the $^2\Sigma$, $^2\Pi$CH band with head at λ3871. The band at λ3865 has been measured. It is found that the normal $^2\Pi$ state is almost pure Case *b*, being much more nearly so than the analogous state of CH. This is made manifest by the fact that the R_1 and R_2, the P_1 and P_2 and the Q_1 and Q_2 branches are coalesced to form an apparent three branch band. It is only for $K \leq 3$ that, on the 35-foot grating plate, branch lines can be resolved into very narrow doublets. From term differences the constants B_0' and B_0'' for this band have been calculated as 6.88 and 7.70 respectively. The corresponding constants for CH when multiplied by ρ^2 give 6.80 and 7.65. The agreement is about as good as might be expected since the relation $\rho^2 = B^i/B$ holds strictly only for B_e^i/B_e and not for B_v^i/B_v.

10. The Methane Content of the Giant Planet Atmospheres. ARTHUR ADEL, *University of Michigan,* AND V. M. SLIPHER, *Lowell Observatory.* (*Introduced by D. M. Dennison.*)—The identification of more than forty vibration-rotation absorption bands in the photographic region of the spectra of Jupiter, Saturn, Uranus and Neptune as due to the methane molecule is ample evidence of the vast amounts of this gas present in the atmospheres of the Giant planets. The most outstanding and penetrating harmonic sequence of bands in the planetary spectrum is $n\nu_3$. This sequence extends to $7\nu_3$ (543$\mu\mu$) in the spectra of Jupiter and Saturn, to $8\nu_3$ (486$\mu\mu$) in the spectrum of Uranus, and to $9\nu_3$ (442$\mu\mu$) in the spectrum of Neptune. The quantities of methane present in the absorbing layers of the planets (the layers penetrated by sunlight before it is scattered back into interplanetary space) can be determined from the path-lengths required to display these sequence limits in the laboratory. Path-lengths of sufficient magnitude were used to photograph down to and including $7\nu_3$, thus providing a direct estimate of the methane content of the absorbing layers of Jupiter and Saturn. The methane concentrations in the absorbing layers of Uranus and Neptune were secured through extrapolation along a curve which was obtained by plotting a characteristic of the sequence $n\nu_3$ against n. Preliminary values for the absorbing layer depths are:

Jupiter — ½ Mile-Atmosphere
Saturn — ½+ Mile-Atmosphere
Uranus — 4 Mile-Atmospheres
Neptune—25 Mile-Atmospheres.

These values yield the following absorbing layer methane contents:

Jupiter — 8×10^{16} tons
Saturn — 6×10^{16} tons
Uranus — $8^+ \times 10^{16}$ tons
Neptune—60×10^{16} tons.

11. On the Intensity Formulas for $^3\Sigma^+ - {}^3\Sigma^-$ Transitions in Band Spectra. R. D. PRESENT AND J. H. VAN VLECK, *Harvard University.*—G. Herzberg has recently studied certain faint absorption bands in O_2 which show Q branches ($\Delta K = 0$) but not the customary P and R branches ($\Delta K = \pm 1$). These bands he attributes on the basis of the configuration theory to a transition $^3\Sigma_g^- - {}^3\Sigma_u^+$. Such transitions are forbidden by the usual selection rules and have hitherto not been observed. There exist two alternative explanations for the occurrence of these bands: (1) spin-orbit interaction, (2) rotational distortion. Both of these effects would cause the Σ states to assume some of the characteristics of Π states; consequently the forbidden bands would appear with small intensity. For the case of spin-orbit interaction the intensities have been calculated in case (a) and transformed to case (b) where the theory predicts twelve branches with $\Delta K = \pm 2, 0$ provided the J structure is resolved. When this structure is unresolved we find that transitions with $\Delta K = 0$ should be more intense than transitions with $\Delta K = \pm 2$ in the ratios: 6 : 1 when $K \doteq \infty$, 5 : 1 for $K = 5$ and 4 : 1 for $K = 1$. In view of the faintness of the observed bands this appears to be sufficient to account for the absence of branches with $\Delta K \neq 0$. With rotational distortion, calculations show that only Q branches will occur. With spin-orbit interaction the intensities vary approximately as the first power of K, while for rotational distortion they increase asymptotically as K^3. Further experiments are needed to decide between the two explanations.

12. Transfer of Rotational Energy. FOSTER F. RIEKE, *Harvard University.* (*Introduced by O. Oldenberg.*)—HgH bands are emitted when a mixture consisting of traces of Hg vapor and H_2 and a few mm of N_2 is irradiated with the Hg 2537 line. Their appearance is known to be a consequence of two reactions involving metastable Hg atoms: (1) formation of HgH in its normal electronic state and (2) excitation. In the interval between these processes, and between successive excitations, the HgH makes thousands of collisions with normal N_2 molecules. The interval between processes, and therefore the number of collisions, is inversely proportional to the concentration of excited atoms and can be increased by reducing the intensity of the exciting radiation. Experiments show that the rotational temperature, always greatly in excess of the temperature of the gas, decreases with decreasing intensity of the primary light. Additional experiments show that the phenomenon is not caused by self-absorption of the

low-rotation lines; and moreover it is not to be explained by the influence of higher states of Hg excited by successive absorptions. The result may be interpreted as evidence of extremely slow decay of rotation of HgH in collisions with N_2. Other experiments indicate that the principal source of excess rotation is not the formation process, as Beutler and Rabinowitch assumed, but transfer of vibrational or electronic energy into rotation during the lifetime of the excited molecule.

13. The Far Ultraviolet Absorption Spectra and Ionization Potentials of H_2S, CS_2 and SO_2. W. C. PRICE, *The Johns Hopkins University.*—A new absorption spectrum has been found in H_2S in the region below 1650A. The rotational structure of a few of the bands has been resolved. They have *P*, *Q* and *R* branches and are shaded towards the red. Their structure indicates that the moment of inertia is not changed by more than a few percent by the excitation. The bands with possibly one or two exceptions are all due to the vibrationless electronic transitions of a non-bonding electron. Three Rydberg Series going to a limit of 84,420 cm^{-1} and one going to a limit of 84,510 cm^{-1} were found in the bands. Up to 15 members were found for one series. The ionization potentials of H_2S can thus be given as 10.414 ± 0.002 and 10.425 ± 0.003 volts. Absorption spectra of CS_2 and SO_2 have been found in the region 2300–1000A. These consist of various sets of long vibrational progressions which widen out to either side with increasing pressure. A consideration of the bands indicates that they both go to ionization potentials around 10.3 volts. In the case of SO_2 however, there is a much stronger set of bands starting around 1350A. These are probably the bands which go to the observed ionization potential at 13 volts.

14. A Spectroscopic Investigation of Chemical Reactions of OH in the Electric Discharge. A. A. FROST AND O. OLDENBERG, *Harvard University.*—Through light absorption as observed with the aid of the 21-ft. grating, relative concentrations of OH may be measured. OH produced by the electric discharge through H_2O vapor has a lifetime of the order of $\frac{1}{8}$ of a second. Measurements of the OH concentration as a function of the time after interruption of the discharge and as a function of the total pressure indicate that the chief process by which OH disappears is the three-body process $OH + OH + M \rightarrow H_2O_2 + M$.

15. Extension of the Absorption Spectrum of the Hydrogen Molecule. JOHN J. HOPFIELD, *Libby-Owens-Ford Glass Co.*—Using the continuous spectrum of helium as a background, discrete absorption lines (bands) have been observed in H_2 at low pressures as far as 738A. Some bands belong to the $A-D$ system already reported and the rest belong to new systems. Some of these bands extend into the region above the ionization potential of H_2 (15.9 v), that is, into the region of vibration in the normal electronic state of the hydrogen molecule ion. Apparently they are the higher vibration states of band systems of H_2 which begin below this ionization limit. This lends further evidence in support of the correctness of the above value of the ionizing potential of the molecule. The $A-D$ band system has already been described. An alternative interpretation has been suggested by Richardson in his recent book. His interpretation does not seem to fit the absorption data if normal spectral behavior is the rule in the case. No new vibration bands of this system are evident to change the vibrational analysis that had already been given by the author. The $A-D$ band system, one of the strongest in the spectrum of the hydrogen molecule, seems therefore to remain unclassified in the present scheme of H_2.

THURSDAY MORNING AT 10:00 O'CLOCK

Bureau of Standards

Chemistry Building, Lecture Room

16. Effect of Visible Light upon the Ultraviolet Fluorescence of Various Compounds Previously Irradiated with Roentgen or Gamma Rays. OTTO GLASSER AND I. E. BEASLEY, *Cleveland Clinic Foundation.*—The ultraviolet fluorescence of sodium chloride, potassium chloride, sodium bromide, rocksalt and fluorite crystals following their exposure to roentgen or gamma radiation is conspicuously increased if the irradiated compounds are exposed to visible light. Intensity and quality of the emitted ultraviolet radiation was measured with a photo-electric Geiger-Mueller counter tube equipped with a cadmium electrode and a quartz window. The half life of induced ultraviolet fluorescence ranges from a few minutes to several days depending upon the intensity and duration of exposure to the primary radiation and the subsequent exposure to visible light. Spectrographic examination in the case of sodium chloride shows that the emitted radiation has one maximum in the neighborhood of 2450A.

17. Optical Properties of Lithium Fluoride in the Schumann Region. EDWIN G. SCHNEIDER, *Harvard University.*—Vacuum spectrograph measurements on artificially produced lithium fluoride crystals have been made to determine the absorption, reflecting power and index of refraction in the extreme ultraviolet. The absorption coefficient and reflecting power were determined by photographic measurement of the transmission of several thicknesses of lithium fluoride taken from the same crystal. For this reason the term reflecting power includes all surface mechanisms acting to remove light from the transmitted beam. A comparison of the measurements on polished and on cleavage surfaces shows very nearly the

same values for reflection. These values are considerably higher than the theoretical curve for short wavelengths, but approach this curve for longer wavelengths. This discrepancy is similar to that found by W. M. Powell (Phys. Rev. **45**, 154 (1934)) for fluorite. The absorption coefficient for the best crystal was found to increase slowly from 0.3 per cm at 1600A to 1.0 per cm near 1200A. Below this point it increases rapidly. The refractive index was determined by the method of minimum deviation. In the near ultraviolet the values obtained are in complete agreement with those of Z. Gyulai (Zeits. f. Physik **46**, 80 (1927)). At 1130A the index has increased to 1.70.

18. The Electro-Optical Kerr Effect in NH_3, N_2 and O_2. WILLIAM M. BREAZEALE, *University of Virginia.* (*Introduced by J. W. Beams.*)—Absolute values for the Kerr constant of anhydrous ammonia, nitrogen and oxygen have been determined. The apparatus used was an improved form of that first developed by Stevenson and Beams (Phys. Rev. **38**, 133 (1931)). NH_3 and N_2 were measured directly, but the fire hazard prevented doing this with O_2. Instead the Kerr constant was determined for a mixture of N_2 and O_2 and the value for O_2 deduced from this and the known value for N_2. Measurements in NH_3 were made using wavelengths of 6500A and 5750A, pressures from 13 to 30 atmospheres and temperatures from 40 to 80°C. In N_2 and O_2 the wavelength used was 6500A, pressures in the neighborhood of 100 atmospheres and temperatures from 20 to 65°C. The absolute value of the Kerr constant B reduced to 6500A and N. P. T. is for NH_3 $(64.2\pm1.8)10^{-12}$, for N_2 $(4.60\pm0.10)10^{-12}$ and for O_2 $(6.94\pm0.30)\ 10^{-12}$. These values are in agreement with the predictions of the Langevin-Born theory.

19. Diffuse Infrared Transmission of Solids. J. D. HARDY AND CARL MUSCHENHEIM, *New York Hospital.*—In the course of experiments on the total amount of infrared energy transmitted through human skin it was found necessary to develop a method for measuring the energy scattered when Lambert's law was not obeyed. Angstrom's law of scattering was found to fit the experimental data and a simple integration method was used to determine the total energy transmitted. Such materials as ground glass, white bond paper, and human epidermis were examined. The method was tested by measuring the transmission of a piece of glass before and after grinding. It was found that the two were in satisfactory agreement; the glass after grinding transmitting about 5 percent less than before. Layers of skin as thin as 0.03 mm were found to have strong absorption maxima due to water; upon drying the skin, the bands due to the organic linkages became apparent.

20. Color Temperature Scale of the Nela Laboratories. W. E. FORSYTHE, *Incandescent Lamp Department, General Electric Company, Nela Park.*—The color temperature scale for the laboratories at Nela Park has been maintained by a number of tungsten lamps which had been color matched against carbon tube and various platinum wound porcelain black bodies. The platinum wound furnaces were operated at temperatures between 1300 and 1828°K and the carbon tube furnace between 1600 and 2600°K. Above 2600°K the color temperatures were determined by indirect methods, making use of several hollow tungsten tube black bodies used by Dr. A. G. Worthing[1] in measuring the emissivity of tungsten. About a year ago the National Bureau of Standards[2] announced the establishment of a new color temperature scale. To check our color temperature scale with this new scale, a number of tungsten lamps were sent to the Bureau with the request that these lamps be color matched with their standards. It was found that our temperature scale was about 26° low at 2400°K and about 26° low at 2800°K. Since it does not seem that the incandescent lamps used to maintain this scale have changed in the past 10 years, this 26° deviation indicates a real difference between the two scales.

[1] Phys. Rev. **10**, 377 (1917).
[2] B.S. Jour. Res. **12**, 527 (1934).

21. Molar Polarization of Nitrogen and Argon by Displacement Interferometry. CLARENCE E. BENNETT, *University of Maine.*—(Experimental data obtained at Massachusetts Institute of Technology.) An improved displacement interferometer suitable for precise measurements of dispersion in gases over ranges of pressure and temperature was described about a year ago.[1] At that time it was pointed out that for pure nitrogen, because of a strictly linear variation of fringe displacement with pressure up to 14.145 atmospheres, it was possible to calculate simultaneously the Cauchy dispersion constants A and B corresponding to N.T.P. conditions and infinite wavelength. $A-1=0.002932$ and $B=1.637\times10^{-14}$ to 0.1 percent. More recently, the pressure readings in these nitrogen experiments have been reduced to corresponding density values by a Keyes type equation of state.[2] $p=RT/(v-\beta e^{-\alpha/v})-A/(v+b)^2$. As a result, it now becomes possible to state that the Lorentz-Lorenz relation is valid to one part in fifteen hundred for densities up to 0.01656 gram/cc. Furthermore, the molar polarization is found to be 4.369 ± 0.003. Also, similar observations and calculations have been made for argon of purity known to exceed 99.8 percent, over a range of densities from zero to 0.03342 gram/cc (18.482 Atmos.) involving two different temperatures. Although the fringe displacements deviate slightly from linearity with pressure in this case, they are linear with density to less than six parts in three thousand. Therefore the Cauchy dispersion constants A and B for N.T.P. conditions and infinite wavelength are obtainable with a precision approaching that in the case of nitrogen. The values are: $A-1=0.0002776$ and $B=1.459\times10^{-14}$. Also, the Lorentz-Lorenz relation is strictly followed (the average deviation being less than 0.2 percent), and the molar polarization is found to be 4.136 ± 0.010. Preliminary calculations on CO_2 data over the density range from zero to 0.03839 gram/cc indicate that the Lorentz-Lorenz equation is not followed.

[1] Phys. Rev. **45**, 3 (1934).
[2] Proc. Nat. Acad. Sci. **3**, 323 (1917).

22. Theory of Photoelasticity. HANS MUELLER, *Massachusetts Institute of Technology.*—Elastic deformations cause birefringence because they produce anisotropy of (1) the Lorentz forces, (2) the Coulomb forces in ionic crystals and (3) the atomic polarizabilities. For D-lattices

and amorphous solids the photoelasticity due to the first two effects is calculated from Ewald-Born's lattice potentials. Comparison with experimental data shows that in most cases the third effect is predominant. For pressure the anisotropy of the atomic refractions always causes negative birefringence. Positive birefringence occurs only if the first two effects give a large positive contribution. This is the case for highly refractive glasses, for ZnS, CaF_2 and CsCl for pressure normal to an octahedral face, and for crystals of the type NaCl if the pressure is normal to a cube face and if the ratio of the refractions of the anion and cation is less than 10. In some cases this ratio can be calculated from the photoelastic constant p_{44}. Diamond and zincblende show a large photoelastic effect for pressure normal to a cube face because the first and third effects give both negative birefringence. The optical anisotropy produced by pressure is larger for anions than for cations. Hydrostatic pressure decreases the refractions.

23. Quantum Theory of Metallic Reflection. L. I. SCHIFF AND L. H. THOMAS, *Ohio State University.*—In the classical (Drude) theory of the reflection and refraction of light at a metallic surface, the component of electric intensity perpendicular to the surface is discontinuous there, the remaining components of the field vectors being continuous. In a more detailed description the interaction of the light with the metal is expressed as scattering by the conduction electrons according to quantum theory. Those components of the field vectors which were continuous in the classical theory retain very approximately their values in that theory. The electric intensity perpendicular to the surface, though given approximately elsewhere by the classical theory, fluctuates widely within a few electron wavelengths of the surface. If this fluctuating field is used to calculate the surface photoelectric effect by Mitchell's method (K. Mitchell, Proc. Roy. Soc. **A146**, 442 (1934)), the agreement of his result for a clean potassium surface with observation seems to be improved. No calculations have been made for sensitized surfaces, but arguments based on the use of the Drude form seem to be precarious.

THURSDAY AFTERNOON AT 2:00 O'CLOCK

Bureau of Standards

East Building, Lecture Room

24. The Half-Lives of Potassium, Rubidium, Neodymium and Samarium. ARTHUR E. RUARK AND KARL H. FUSSLER, *University of North Carolina.*—The long apparent half-lives of K, Rb and Nd are in striking disagreement with theory. To relieve this discrepancy, at least in part, the suggestion has often been made that their activities are due to isotopes of small abundance, having half-lives small in comparison with the apparent ones. This paper shows that the active fractions have half-lives longer than 10^8 years; the same is true for the alpha-rayer Sm. It is pointed out that these activities may be caused by small radioactive fractions of well-known isotopes; RaD and stable Pb 210 constitute a similar case. Data are presented which show that it is possible for the active portions of Nd and Sm to be genetically connected.

25. The Hollow Cathode as an Ion Source. P. GERALD KRUGER AND B. T. DARLING, *University of Illinois.*—A Paschen hollow cathode has been set up in a way similar to that used in a vertical type lamp for the excitation of spectra. Various sized holes were made in the bottom of the cathode and an electrode, at 1000 v negative potential, placed a few mm from the bottom, to see what magnitude of positive ion current could be drawn from the cathode. A pressure of about 100 bars of He gas was maintained in the lamp and the cathode glow excited by a 700 v d.c. potential. Table I shows the order of magnitude of ion currents which can be obtained. Apparently the ion current is directly proportional to the lamp current and the area of the hole in the cathode. The total power used in the experiment so far has been 350 watts. No ion current is observed when the accelerator voltage is applied to the accelerator electrode and there is a zero current through the lamp.

TABLE I. *Positive Ion Current from Hollow Cathode.*

AREA OF HOLE CM^2	ION CURRENT MICROAMP.	LAMP CURRENT AMP.	ACCELERATION POTENTIAL VOLTS	ION CURRENT PER CM^2 PER 0.5 AMP. LAMP CURRENT M.A.
1.64×10^{-3}	5	.50	1000	3.0
6.7	18	.50	1000	2.7
22.8	60	.50	1000	2.7
43.8	65	.25	1000	3.0
43.8	110	.40	1000	3.1

26. Electrostatic Generator with Small Vertical Clearance. WILLARD H. BENNETT, *Ohio State University.*—In order to obtain the highest possible voltage on an electrostatic generator in a room with a ceiling twelve feet high, the collecting surface for charge at high voltage is supported by ropes at 20° with the horizontal. This exposes smooth surfaces having a maximum radius of curvature towards the nearest grounded surfaces (above and below) and also avoids having dielectric surfaces in the gap. Tests on the generator show that both of these points of design are important.

27. A High Current Ion Source. E. S. LAMAR AND E. W. SAMSON, *Massachusetts Institute of Technology.*—Since the capillary ion source described by Tuve, Dahl and

Van Atta (Phys. Rev. **46**, 1027 (1934)) was a decided advance over previous types, it seemed desirable to investigate its possibilities further. In the present source, as in theirs, the arc runs through an $\frac{1}{8}$ inch capillary in a stainless steel block. The essential modifications are the use of glass insulation for cathode and anode, and elimination of the auxiliary electrode for drawing ions out of the arc. The ions simply drift through a 1.18 mm outlet tapered to a 45° edge. The ranges of current, voltage and gas pressure in the arc were 0.1 to 3.5A, 80 to 100v, and 0.04 to 0.6 mm. The ion current is approximately proportional to arc current when the outlet is tapered, and depends little on pressure, but varies greatly with outlet shape and gas purity. A 1.92A arc current gave 4.2 milliamperes, which converged into a 12 mm beam at 8 cm from the outlet when 10 kv was applied to a 2.5 cm focusing electrode placed at a distance of 4 cm. Two groups of secondaries were produced by positive ions striking the collectors, one group roughly independent of voltage, the other rising sharply at 8 kv.

28. The Efficiency of the Tube Counter. SELBY M. SKINNER, *Columbia University.*—The efficiency of counting ionizing particles by the tube counter is investigated, taking account of the electrical behavior of the counter, and the random nature of the arrival of the particles. Expressions are obtained for the efficiency of counting, the number of particles counted per unit time (n), and the average recovery time, in terms of the number of particles arriving per unit time (n_0), the time constant of the counter, and one other parameter, d, which is constant for a given counter. Methods for measuring d (which for most counters lies between 1.3 and 5) are indicated. The efficiency of counting decreases with an increase of n_0, rapidly at first, then more slowly, so as to have the asymptotic value $1/d$. The determination of n_0 from n is discussed.

29. Characteristics of Geiger-Müller Counters Filled with Different Gases. C. L. HAINES, *Bartol Research Foundation.*—Nine counters of the metal-glass type were made, having oxidized copper cylinders 1 cm in diameter and 3 cm long. Tungsten wires of 3 mils diameter were put into one group of three, of 5 mils into another, and of 10 mils into the third. Air, hydrogen, oxygen, argon (oxygen-free) and argon-oxygen mixtures in the approximate proportions 94 percent A and 6 percent O_2 and 99 percent A and 1 percent O_2 were used at pressures from 1 to 100 mm of Hg. Starting voltage *vs.* pressure was measured for each gas and each wire size. A crossing of the three curves for each gas is shown; indicating that the starting voltage is lower for the larger wire, at low pressures, than for the smaller wire. The starting and breakdown voltages were determined when the counter resistor was only 10^6 ohms, and the difference between these two voltages taken as a measure of the operating range of the counter. Counting rate *vs.* pressure was also measured for each gas, using a constant radioactive source. Werner's equation (Zeits. f. Physik **90**, 384 (1934)) is shown to fit the data well for the pure gases and fairly well for the argon-oxygen mixtures, but not so well in the case of air.

30. New Methods for the Detection of Minute Quantities of Thorium in Common Materials. ROBLEY D. EVANS,* *Massachusetts Institute of Technology*, GLADYS D. FINNEY, ARTHUR F. KIP AND RAYMOND MUGELE, *University of California.*—Advances in geophysical radioactivity and in age measurements on meteorites, igneous rocks and other common materials await development of precision technique for the determination of minute traces of thorium and its radioactive products. Our experimental results show the Th emanation-flow-technique to be inherently inefficient, as the emanating power of liquid specimens may vary and is at best only about 0.6. We have therefore developed four new methods for thorium detection based on (1) vacuum-tube-electrometer counting of all alpha-rays emitted from smooth surfaces of solids, such as polished rocks, (2) counting of all alpha-rays emitted from powdered specimens, such as finely ground rocks or chemically prepared precipitates, (3) counting of ThC′ alpha-rays only, after exclusion of all shorter rays by absorbers placed over solid or powdered sources, (4) detection of the feeble gamma-rays emitted by larger sources, using very sensitive screen-cathode γ-ray tube-counters. Methods 1, 2, 4 require corrections for radiations due to the uranium series, and these are based on accurate radium analyses. Method 3 reaches the Th series directly. Method 2 gives a direct measure of the rate of production of helium, when very thin sources are used. Methods 2, 3, 4 may be referred to internally standardized sources, but Method 1 cannot, and is, moreover, subject to difficulties due to the escape of traces of emanation from the source. We find it least reliable for routine work. Analyses of a suite of Sierra Nevada igneous intrusive rocks showed that Methods 2 and 4 are most suitable and give mutually consistent results. They also indicate that the ratio of Th/U is higher than previously supposed and that therefore thorium determinations are even more important to geophysics than had been previously supposed.

* National Research Fellow, University of California, 1932–1934.

31. Theories of Ion Condensation. DONALD H. LOUGHRIDGE, *University of Washington.*—The very great importance of cloud expansion photography in the field of nuclear investigations has brought sharply to the front a need for suitable correlation of physical and chemical properties of liquids and their suitability for ion condensation. Results obtained on minimum expansion ratios for alpha-ray track condensation, in a large number of organic vapors, are compared on the basis of the original Thomson theory and the new one of Volmer and Flood, with good agreement in most cases on the latter basis. The radii assumed for these calculations are taken from the best experimental values for the cases available. The effect of the size of the chamber on the assumption of adiabatic expansion, by considering the effects of heat conductivity, is plotted.

THURSDAY AFTERNOON AT 2:00 O'CLOCK

Bureau of Standards

Industrial Building, Room 301

32. The Raman Spectra and the Latent Heat of Fusion of Nonassociated Substances. C. J. PHILLIPS, *Corning Glass Works.* (*Introduced by J. T. Littleton.*)—The relationship

$$\lambda = mNhc/JML_f = m(2.845 \times 10^{-1})/ML_f,$$

where $m = 1, 2 \cdots$, N = Avogadro's number, h = Planck's constant, c = velocity of light, J = Joule's equivalent, M = molecular weight, and L_f = latent heat of fusion, is applied to thirty-eight organic and inorganic substances in the crystalline and liquid states. The wavelengths calculated in this way are found to agree quite closely with the observed infrared absorption bands. For each substance a Raman shift can be found which is equal to the calculated frequency, both being expressed in wave numbers. In all but five cases, the calculated Raman shifts lie within the range 350 cm^{-1} to 1600 cm^{-1}, although the molecular weights vary in a 6 to 1 ratio and the latent heats of fusion in a 21 to 1 ratio. The relationship apparently holds only for nonassociated substances. There are remarkable similarities between the calculated values for various homologous compounds. It is suggested that in glass the SiO_2 group may vibrate independently, at least to a certain extent.

33. The Complete Raman Spectrum of Heavy Chloroform. R. W. WOOD, *The Johns Hopkins University,* AND D. H. RANK, *Pennsylvania State College.*—The complete Raman spectrum of heavy chloroform has been photographed. Two distinct isotope effects were found and the calculations agree well with the observations. The 3318 frequency difference is shifted to 2256. The probable error is one wave number.

34. Diffraction Gratings for Use in the Far Infrared. A. H. PFUND AND J. A. SANDERSON, *The Johns Hopkins University.*—Glass halftone plates (Levy screens), the surfaces of which consist of alternate polished bars and etched grooves, have been silvered chemically and used as diffraction gratings in the far infrared: 25μ–100μ. The surfaces of the gratings have been prepared as follows: (1) the entire surface of the halftone plate was silvered, (2) the polished surfaces were silvered and the grooves filled with $CaSO_4$, which is black in the far infrared. No great differences in the behavior of the two types have been found. From 75 to 100 orders of the green mercury line can be seen on one side of the central image in the spectrum formed by these gratings as compared with about 20 visible orders in the spectrum formed by a wire grating. This indicates that the resolving power of the halftone plates should exceed that of wire gratings. By using filters of paraffin and black paper, energies measured in the central image are about one-fifth as great as the energy obtained by reflection from a silver mirror. Large radiometer deflections up to wavelength 100μ have been obtained. This work indicates that although the energy obtained from the halftone plates is not as great as that from echelettes, the resolving power is comparable to that of the echelette. The gratings are easily prepared; the cost is quite nominal.

35. Powder Filters for the Infrared. R. BOWLING BARNES, R. ROBERT BRATTAIN AND R. S. FIRESTONE, *Princeton University.*—The infrared transmission of thin layers of finely divided crystals of uniform particle sizes has been measured. Such layers are found to be opaque to radiations where $\lambda \ll \rho$, where ρ is the average diameter of the particles, and transparent to radiations where $\lambda \gg \rho$. If a characteristic frequency of the crystal lies in the region of opacity a sharp maximum of transmission is found upon the short wavelength side of this absorption band. Pfund has studied filters of this type. The use of such filters enables one to obtain very sharp monochromatic bands of infrared radiation. The explanation of the behavior of such powder filters lies in the fact that in regions where $\lambda \ll \rho$, the waves are refracted by the relatively large particles and emerge from the layer in random directions giving rise to an apparent opacity. In the region where $\lambda \gg \rho$ the particles are too small to act as refracting centers, and the only intensity loss is by scattering. At some point on the short wavelength side of the crystal frequency, the refractive index becomes equal to 1, and no refraction takes place. Hence the sharp transmission maximum. The true absorption of the crystal helps sharpen this maximum. It will be recognized that the origin of the sharp transmission band is the well known Christiansen filter effect.

36. The Infrared Spectrum of GeH_4. WENDELL B. STEWARD AND HARALD H. NIELSEN, *Ohio State University.*—The absorption spectrum of GeH_4 in the infrared has been investigated with a prism spectrometer to 13.0μ, and bands, enumerated in the order of their intensities, have been located at 12.0μ (833 cm^{-1}), 4.7μ (2125 cm^{-1}), 3.3μ (3031 cm^{-1}), 3.4μ (2923 cm^{-1}), 6.0μ (1666 cm^{-1}) and 2.2μ (4545 cm^{-1}). The regions at 3.3μ and 4.7μ have been measured under higher dispersion using an echelette grating ruled with 3600 lines per inch, in second order, and an echelette grating ruled with 4800 lines per inch in first order, respectively. The 3.3μ region consists of at least two overlapping bands and has only incompletely been resolved. The 4.7μ region consists of a single band with a very strong Q branch converging toward lower frequencies. The individual lines in the P and R branches are quite well resolved and give evidence of a more complex structure. The spacing between the principal peaks appears to be about 4.8 cm^{-1}. By analogy to the spectrum of methane the bands given above are identified respectively as ν_4, ν_3, $\nu_1+\nu_4$, $\nu_3+\nu_4$, $2\nu_4$ and $2\nu_3$.

37. The Infrared Absorption Spectrum of MgO. R. ROBERT BRATTAIN, R. BOWLING BARNES AND FREDERICK

SEITZ, *Princeton University.*—By using plates, ranging in thickness from 0.075 mm to 3.05 mm cleaved from large single crystals of MgO, the infrared absorption spectrum of this substance has been studied. The absorption spectrum of this cubic crystal was found to consist of several prominent peaks and additional fine structure. An explanation of this is being sought on the basis of the three-dimensional lattice theory, in which harmonic and anharmonic terms are taken into account. Additional experiments are being performed to check preliminary results of the theory.

38. The Absorption of the Acetylenes in the Photographic Infrared. CHARLES A. BRADLEY, JR. AND ANDREW MCKELLAR, National Research Fellows, *Massachusetts Institute of Technology.*—By using an absorbing column 9 meters long of over 90 percent pure C_2D_2 at a pressure of 85 cm, no absorption bands were observed in the region 7000–11,700A. Inasmuch as it can be calculated on the basis of the vibrational assignments of the C_2H_2 bands taken in conjunction with the predicted frequencies for C_2D_2 that several bands should be present in this region under the above conditions, the lack of absorption is somewhat surprising. Possible causes of this unexpected behavior are discussed. A new faint absorption band of C_2H_2 was photographed in the first order of a 21-foot grating. For this an absorbing column of 7.5 meters in length at 90 cm pressure was required. The band's origin occurs at 12,720 cm^{-1} (7859A). It may arise from the combination $\nu_1+3\nu_2+2\nu_5$ which should occur (using Herzberg and Spinks' constants) at 12,708 cm^{-1}. We are indebted to Professors H. C. Urey and J. E. Zanetti of Columbia University for the D_2O and specially prepared CaC_2 used in generating the C_2D_2 and to Professor E. F. Barker of the University of Michigan for testing the purity of a sample of the gas.

39. The Infrared Absorption Spectra of Acetic Acid and Acetic Anhydride. E. K. PLYLER AND E. S. BARR, *University of North Carolina.*—Acetic acid and acetic anhydride show bands in the regions of 1.9, 2.3, 2.5 and 2.8μ. There is a slight variation in position and intensity but the two spectra are similar. In the region of 5.5μ there is an intense band in the acetic anhydride spectrum. When water is present acetic acid has a strong band at 5.7μ. A study of the intensities of these two bands made it possible to determine the time of formation of acetic acid from the anhydride and water. When 1 mole of water and 1 mole of anhydride were kept at 70°C, 50 percent of the anhydride had reacted in 45 minutes. At 26°C the change required approximately 12 hrs. Other factors being constant, increasing the mole fraction of water increases the rate of reaction, and decreasing the mole fraction of water decreases the rate of reaction.

THURSDAY AFTERNOON AT 2:00 O'CLOCK

Bureau of Standards

Chemistry Building, Lecture Room

40. The Production of Very Small Electric Currents. GEORGE J. MUELLER, *Cornell University.*—Through improvements in construction and an extension of its range, the device for producing small electric currents of known magnitude described by Smith[1] has been developed into an exceedingly useful and reliable laboratory instrument. Experiments indicate that the device is convenient as a source of small known quantities of both positive and negative charge. Some unusual results of a careful study of expected tube constants as determined from electrode dimensions and experimentally determined values as well as constructional details and associated apparatus are described.

[1] L. P. Smith, *A Device for Obtaining Very Small Electric Currents of Known Magnitude,* R. S. I. 2, 237 (1931).

41. A Rotating Coil Alternating Current Potentiometer. WALTER C. MICHELS AND BARBARA RAINES, *Bryn Mawr College.*—An apparatus of high voltage and current sensitivities for the measurement of low frequency alternating currents has been constructed. The small potential difference to be measured is opposed to a sinusoidal electromotive force generated by a coil rotating in the magnetic field of a set of Helmholtz coils. The rotating coil is driven by a synchronous motor and the amplitude and phase of the opposing electromotive force can be varied by control of the Helmholtz coil currents. The detecting instrument is a three-stage amplifier supplying a tuned vibration galvanometer. Sensitivities of the order of 10^{-5} volt/mm or 10^{-14} ampere/mm are obtainable. Since the amplifier is used only as a null instrument, difficulties due to nonlinearity do not arise.

42. The Use of Thermionic Vacuum Tubes for Voltage Control. CHAS. R. LARKIN, *Lehigh University.*—The use of thermionic vacuum tubes to maintain a constant high potential supply for Geiger-Müller counters and ionization chambers is now quite common. Johnson and Street[1] devised two such circuits, and following them several modifications have been published. Under certain conditions some of these circuits may develop a seriously large damped oscillation which is not controlled by the regulator tube and which is not detected by a d.c. meter in the output. A study of these fluctuations in the various regulators has been made and is here presented. Several simple methods are available for reducing or eliminating them in the output. The overall control characteristics of the several circuits are compared and data on their performance are given. A modified two-tube circuit having

better characteristics than any so far examined, is described.

[1] J. C. Street and T. H. Johnson, J. Frank. Inst. **214**, 155 (1932).

43. On the Nature of the Barrier Plane in the Cuprous-Oxide Photovoltaic Cell. JAMES W. BALLARD, *University of Pittsburgh*, AND E. D. WILSON, *Westinghouse Electric and Mfg. Co.*—Two possible internal structures of cuprous-oxide photovoltaic cells are considered, one in which the semi-transparent metal is either in intimate contact with the oxide or at most separated from it by a short gap, and one in which the semi-transparent metal is separated from the oxide by a polarized layer. Potential energy diagrams, representing approximately the potential energy of an electron in these two assumed structures, are drawn and transmission coefficients are calculated and plotted for incident light of wavelength range from 4000A to 6500A. Experimental results, obtained by means of "synthetic cells" purposely constructed to emphasize one or the other structure, are presented and discussed. Both theoretical and experimental evidence indicates the second postulated structure is more likely to explain the photovoltaic effect.

44. On the Peculiarities of Dielectric Constant *versus* Pressure Curves for Vapors. J. D. STRANATHAN, *University of Kansas.*—Deviation from linearity of the curve of $(K-1)/(K+2)$ *versus* pressure for many vapors has been attributed to various causes, most generally to a conductivity effect. The author finds in the case of water vapor, which gives an unusually large deviation, that the break is definitely not due to conductivity. Data show definitely that it is due to adsorption on the insulator surfaces and the consequent increase in polarization contributed by these additional molecules. This has been shown experimentally by changing markedly the adsorbing surface without changing the conductivity. In all probability the same phenomenon is responsible for the smaller deviations shown by other vapors.

45. The Variation of Thermal e.m.f. with Magnetization and Temperature. F. WOODBRIDGE CONSTANT, *Duke University.*—The variation of the e.m.f. of a thermocouple when one of the metals is magnetized was first discovered by William Thomson in the case of iron and nickel. This means that a couple may be formed entirely of one material provided the magnetization is not the same throughout. In spite of the many investigations of this effect since Thomson's the results are conflicting and the conclusions confusing. This attempt has been made first to summarize previous work, and second to repeat measurements of the effect on as many different ferromagnetic metals as possible when under exactly the same conditions in order that the resulting data might be more available for interpretation. Fe, Ni, Co and permalloy were tested by comparison of the ferromagnetic metal first unmagnetized and then magnetized in a uniform magnetic field against copper. There are indications of a connection between this effect, the change of length in a magnetic field and crystal structure which is of interest regarding theories of ferromagnetism.

46. The Establishment and Destruction of Superconductivity at Radiofrequency. R. B. SCOTT, F. B. SILSBEE AND F. G. BRICKWEDDE, *National Bureau of Standards.*—A tin wire 0.022 cm in diameter was supplied simultaneously with direct current and with alternating current of 200 kilocycles per second and of such value that the circular magnetic field in the outer layers exceeded the critical value at one crest of each cycle but was less than critical at the other crest. If the resistance of the material followed these pulsations would it be expected that the flow of the alternating current would produce between the ends of the specimen a drop of potential of distorted wave form containing a strong component of double frequency? Such a double-frequency component of the expected value was found. It varied with the temperature and the magnitudes of the components of current in the manner to be expected. It may be concluded that the mechanism of superconduction can come into action or be destroyed within a few microseconds by a sufficiently large magnetic field.

47. A New Phenomenon in the Superconducting Transition of Tin and Tantalum. F. B. SILSBEE, F. G. BRICKWEDDE AND R. B. SCOTT, *National Bureau of Standards.*—The effect of combinations of the variables, temperature, transverse magnetic field and specimen current, on the resistance in the transition range was investigated. The most characteristic effect, noted when the current is large (several thousand amp./cm^2), is that the passage from the superconducting to the normal resisting condition is accompanied by a spontaneous increase in resistance, occupying several seconds, followed by a slower return. This transient resistance is sometimes 75 percent of the normal. After such an effect has occurred, it will not occur again when the same conditions are reestablished after a short interval. The combination of variables at which this effect occurs is, however, definite if the time interval is long enough or if the specimen has been cooled to a low temperature. The effect occurs in two tantalum specimens at approximately the same (apparent) current density. The tin wire requires about 50 percent greater current density. For tin $H=2I/r$ connects, approximately, with specimen radius the currents and fields which acting alone (1) restore a given fraction of the normal resistance and (2) initiate the spontaneous rise. For tantalum the currents required were only 3 to 4 percent of the calculated values.

48. Free Path and Thermoelectric Effects. L. W. NORDHEIM, *Purdue University.* (*Introduced by K. Lark-Horovitz.*)—A general expression for the mean free path of electrons in metals is derived. This expression is valid for high temperatures and for any spherically symmetrical but otherwise arbitrary distribution of eigenvalues. The formulae for the resistance and the thermoelectric phenomena can be obtained in a simple manner for any model of the interaction between the electrons and the ionic lattice. The method is applied to derive relations between changes in the resistance and thermoforce produced by foreign atoms or by distortions. The agreement with the experimental material is fairly good.

Friday Morning at 10:00 O'clock

Bureau of Standards

East Building, Lecture Room

49. Atomic Weights Derived from Nuclear Transmutations. H. A. Bethe, *Cornell University.*—Simple stability considerations require for Be^9 an atomic weight <9.0124 as compared with the mass spectroscopic value 9.0154. Similarly, the excited state of the C nucleus, 5.5 MV above the ground level, should disintegrate into 3 α-particles before a γ-ray could be emitted, if $C^{12}>12.0013$ (Aston: 12.0036). On the other hand, excited O^{16} (5.6 MV energy) should disintegrate into C+He, if $C^{12}<12.0028$. These limits are irreconcilable unless it is assumed that the mass of He^4 referred to O^{16} is much too small. This follows also from the energy balance of nuclear transformations: It agrees perfectly with Bainbridge's mass values for H, He, Li; transmutations of "heavier nuclei" (Be, B, C) into one another agree reasonably well, whereas all transmutations of heavier nuclei into light ones give much less energy than expected. All stability difficulties can be solved, and all energy balances made to agree perfectly, if He^4 is assumed to be 3.0 ± 0.7 parts in 10,000 heavier than hitherto assumed. This correction applies also to H and Li, whose weights have been measured with respect to He. The weights of the heavier atoms are not very much changed. Some atomic weights derived purely from transmutation data are: $n'=1.0085$, $H'=1.00807$, $He^4=4.0033$, $Be^9=9.0134$, $B^{10}=10.0146$, $B^{11}=11.0111$, $C^{12}=12.0037$, $N^{14}=14.0076$, if $O^{16}=16.0000$. The error does not exceed 1 MV in any case.

50. Interaction Between Deuterons and Alpha-Particles. Ernest Pollard and Henry Margenau, *Yale University.*—In a continuation of experiments recently described to this society (New York meeting, Feb. 23, 1935) we have investigated the anomalous scattering of alpha-particles in deuterium for energies near which it first becomes effective; and also the angular variation of the yield of scattered particles for two different velocities of the incident alpha-particle. In each case the recoil deuterons were counted. In the first experiments we found that if the range of the alpha-particle is increased from 1.5 to 2.3 cm, the simple rise in yield of recoil deuterons (as expected from comparison experiments with protons) is not found. Instead there is a rise followed by a drop and a second rise which continues smoothly for higher ranges. We suggest that this maximum is due to resonance with an energy level in the nucleus of $_3Li^6$. The angular scattering experiments show a rapid fall in yield as the angle increases. For low velocities the results agree with Taylor's theory as well as the values found by Chadwick and Bieler do. At higher velocities the agreement is not satisfactory.

51. A Correlation of Nuclear Disintegration Processes. M. Stanley Livingston, *Cornell University,* and Robley D. Evans, *Massachusetts Institute of Technology.*—Bombardment of known elements by energetic alphas, deuterons, protons, neutrons and photons has already led to more than 150 reported modes of artificial nuclear transmutation. Each of the established nuclear reactions, including the 47 cases of natural radioactivity, may, however, be classified under one of 14 generalized type reactions. Compact and readily visualizable charts showing all these 200 or more reactions are presented. Each known isotope is represented by a square on a diagram. With atomic number Z as abscissa, and isotopic weight A plotted in terms of $(A-2Z)$ as ordinates, a simple and orderly arrangement results. A series of straight lines connecting nuclear species then serves to completely portray any reaction. By virtue of their geometrical identity the type reactions stand out with great clarity. Similarly, such matters as the distinction between the artificially radioactive elements which emit positrons and those which emit electrons become sharply significant and general rules for the creation and behavior of new nuclear species may be formulated. When backed by simple mass-energy calculations, the charts facilitate the prediction or verification of new reactions, and suggest the direction for systematic nuclear investigations. Supplementary charts depicting type reactions in a greatly simplified symbolical form will also be shown.

52. Low Voltage Disintegration of Lithium with Lithium. C. A. Whitmer and M. L. Pool, *The Ohio State University.*—The lithium source consisted of a cylindrical steel boiler which had a narrow slit opening at one end and was heated electrically to about 700°C. From the slit a ribbon of atomic lithium issued and passed between two electrodes across which a violent disruptive discharge took place. The lithium ions of various charges then were drawn by an auxiliary voltage into the region of the main acceleration potential of about 120 kv. This potential was obtained by rectifying and smoothing the output of a transformer. It was necessary for the disintegration products to pass through a window of aluminum foil of 2 cm air equivalent before striking a zinc sulphide screen. With a lithium target alpha-particle scintillations were observed at the rate of about one per minute. When the source was adjusted for a less favorable production of multiply charged lithium ions, no appreciable results were obtained. LiOH and LiOD targets gave a somewhat larger alpha-particle count than a pure lithium target; while a beryllium target gave no results. A delayed activity was observed in the zinc sulphide screen indicating perhaps that neutrons as well as alpha-particles are products of the disintegration process.

53. Nuclear Chemistry and the Scattering of Protons in Collisions with Neutrons. David M. Gans and William D. Harkins, *University of Chicago.*—In 1933 the writers with Dr. Newson discovered a new isotope of nitrogen of mass 16, produced from fluorine by bombardment by neutrons. It was assumed that this nitrogen would be radioactive and would emit a negative electron to form

oxygen 16. This has been confirmed by Fermi. A study of the mechanics of nuclear collisions from the relativistic standpoint showed that in nuclear collisions disintegration in no case occurs unless the projectile is captured. Obviously this does not need to hold at the extraordinary energy values of cosmic rays. The scattering of neutrons and protons in their mutual collisions is of fundamental importance in the determination of the nature of the proton and the neutron and their relationship to the positive and negative electron. There is a possibility of an exchange reaction. Experiments on scattering will be described. These exhibit relations which depart from those to be expected for elastic spheres.

54. Absorption and Velocity of Slow Neutrons. J. R. DUNNING, G. B. PEGRAM, G. A. FINK AND D. P. MITCHELL, *Columbia University.*—The question of whether "slow" neutrons approximate ordinary thermal velocities was first studied by Fermi, using artificial radioactivity, with apparently negative results. Using the particles ejected by the slow neutrons from Li, with an ionization-chamber amplifier system as a detector, we have investigated the effect of varying the temperature, from about 95° to 373°K of a cylindrical vessel of water containing a Rn–Be neutron source, on the number of disintegrations produced in Li, and on the absorption coefficient of Cd for these slowed-down neutrons. Three separate experiments gave increases of ionization chamber counts due mostly to Li disintegrations, of 10, 4 and 9 percent, respectively, for "cold" neutrons as compared to "hot" neutrons. Cd absorption of "cold" neutrons measured about 6 percent greater than that of "hot" neutrons. The number of particles counted was so large that the probable statistical error would be less than 2 percent. Certain experimental factors still being investigated make it uncertain how definitely these results indicate thermal equilibrium. The absorption curve of slow neutrons in Cd appears to be completely exponential within experimental limits.

55. Neutron Effects in a Photographic Emulsion. DONALD W. MUELLER AND HENRY A. BARTON, *Princeton University.*—We are investigating the neutrons arising from 100 kv encounters between deuterium nuclei. The neutrons pass through a lead screen to stop charged particles and soft x-rays originating at the target. They then enter a photographic emulsion producing recoil protons and nuclear reactions. Numerous proton and alpha-particle tracks in the developed emulsions are readily observed by means of a binocular microscope with eyepiece half-stops affording stereoscopic vision. A 100 power N.a. 1.3 fluorite oil-immersion objective is used with full aperture illumination. By means of an eyepiece scale and a vertical micrometer, three coordinates are obtainable for any grain. The density of these tracks decreases with distance from the target, being on one plate 40 per sq. mm at a distance of 2 mm. We investigate only those tracks having both ends within the emulsion because only then is the range as well as the orientation determinable. With range and linear grain density known, the data of Blau and Wambacher (Akad. wissens. Vienna, Sitz. ber. **143**, 284 (1934)) enable us to distinguish between α-particle and proton tracks and, in the proton case, the direction of travel. We are proceeding to investigate the energy of the neutrons from the above source. A surprising number of α-particles have been observed which we can only account for as products of interactions between the neutrons and atoms in the emulsion.

56. Collisions of Alpha-Particles with Neon Nuclei. WILLIAM W. EATON, *Yale University.* (*Introduced by A. F. Kovarik.*)—Pure neon was introduced into a Wilson cloud chamber of the piston type, and a large number of photographs taken of the tracks of alpha-particles from a Th C+C′ active deposit source placed outside the chamber. By a system of mirrors, two photographs are taken at right angles on a single motion picture film through a single lens, the image planes being slightly inclined so that all regions of the chamber are in focus. The collisions have been studied by replacing the film in the camera, illuminating and reconstructing the complete forks in space by suitable inclination of a white screen. A device for the rapid and convenient determination of the actual plane of collision is described. The screen is then replaced by photographic paper, and prints taken, which are subsequently analyzed. Calculation of the velocities and measurement of the ranges of the recoil nuclei enable the construction of a range velocity curve. This curve is discussed and compared with Feather's fluorine curve. A number of apparently elastic high energy collisions have been obtained, which are discussed, and examples of these are shown, together with an illustration of the method of recombination of the forks in their original sizes.

57. The Energies of the Beta-Rays and Positrons Emitted by Various Artificially Produced Radioactive Substances. FRANZ N. D. KURIE (National Research Fellow), J. R. RICHARDSON AND H. C. PAXTON, *University of California.*—The energy distribution curves of the β-rays and positrons from radioactive substances produced by deuteron bombardment have been determined from measurements of the curvature of the tracks due to them in a Wilson cloud chamber traversed by a magnetic field. The following table gives our provisional values of the maximum energies together with values of the half-lives as evaluated by others.

Substances	E_{max}	*Half-Life*
$N^{13}+$	1.35 MV	11 min.
$Na^{24}-$	1.45 MV	15.5 hours
$P^{33}-$	1.85 MV	17.5 days
$Cl^{38}-$	4.5 MV	37 min.
$K^{42}-$	2.3 MV	13.5 hours

There is some evidence, as yet unverified, that there are two separate groups of β-rays from radio-chlorine. The two groups found by Cockcroft, Gilbert and Walton in carbon are not found. The data are considered in the light of the Fermi theory and their bearing on the Sargent relation is discussed.

58. An Analysis of the Data on Radioactivity Induced by Neutron Bombardment. CALVIN N. WARFIELD, *Woman's College of the University of North Carolina.*—Acting upon a suggestion of A. E. Ruark a study was made of the literature and the following generalizations were drawn:

(1) Plotting atomic number (Z) against mass number (M) minus Z to represent the transmutations, an orderliness is apparent; (2) $M-Z$ is an even number for each of the 29 known parent isotopes; (3) Z is odd for the 19 parent isotopes which are activated by simple capture or by capture and emission of an alpha-particle, whereas in 8 of the 10 cases in which protons are emitted Z is even; (4) present data indicate that every parent isotope except K 41 is the most abundant natural isotope of the element; (5) all final isotopes resulting from the beta-emission are known stable isotopes; (6) all known final stable isotopes of atomic number less than 30 are the most abundant of the natural isotopes; (7) among the final stable isotopes are found 6 of elements which compose over 90 percent of the earth's crust; and (8) five of these six are activated by capture and emission of a proton, the final stable isotope thereby being identical with the parent isotope, whereas the other (oxygen 16) has not been found to be activated.

Friday Morning at 10:00 O'clock

Bureau of Standards

Industrial Building, Room 301

59. Propagation of Elastic Waves in Lake Ice. A. P. Crary, Maurice Ewing and E. B. Douglas, *Lehigh University.*—Elastic waves were produced in ice on a frozen lake by the explosion of blasting caps and were recorded by electric seismographs. Three components of motion were recorded at distances of 400 to 2000 ft. The magnification of the instruments was determined and the amplitudes and phase relations of the various components of motion were obtained. Longitudinal, transverse and flexural waves were observed and for each type of wave the motion was maximum in its proper plane.

60. Dispersion in Flexural Waves in Lake Ice. Maurice Ewing, A. P. Crary and E. B. Douglas, *Lehigh University.*—In an experiment similar to the one described in the above abstract, the vertical component of motion was measured by three seismographs placed at different points along the path of a train of flexural waves. By this procedure it was possible to follow individual crests over considerable distances and to determine group and phase velocities.

61. The Vacuum Centrifuge. E. G. Pickels, *University of Virginia.* (*Introduced by J. W. Beams.*)—Recent developments have greatly improved the efficiency and operating characteristics of the ultracentrifuge reported previously (Pickels and Beams, Phys. Rev. **47**, 336 (1935)). The starting and stopping of the vacuum rotor has been simplified by the introduction of a new flat bearing type of turbine which is separately supported and driven by two sets of air jets. A larger wire is used for transmitting power from the turbine to the rotor. Other improvements deal with bearings, lubrication, temperature control and arrangements for photographic work. An air pressure of only 15 to 20 lbs./in.^{2} is needed for obtaining ordinarily used forces of several hundred thousand gravity with $3\frac{1}{2}$ inch rotors. With a pressure of 50 lbs./in.^{2}, a simple duralumin rotor of this size, especially shaped for high speeds, was exploded at 156,000 revolutions per minute with the attendant centrifugal force of over 1,200,000 gravity. Photographs of molecular sedimentations in an observational centrifuge demonstrate the possibilities of the apparatus in molecular weight determinations. Good separations of molecules have also been obtained with a newly developed continuous-feed type of centrifuge of 33 cc capacity. Keeping the vacuum chamber at the vapor pressure of the solution being treated reduces frictional effects and prevents evaporation.

62. The Measurement of Young's Modulus in Rocks by a New Dynamical Method. John Ide, *Cruft Laboratory, Harvard University.* (*Introduced by G. W. Pierce.*)—This paper describes a method for determination of Young's modulus for any rigid substance obtainable in rod form. The modulus is computed from the natural longitudinal frequency of the specimen, which is set into vibration by simple electrostatic traction. The test bar forms one plate of an electrical condenser. The other plate is fixed, and separated from the bar by a thin sheet of dielectric. A nonconducting specimen may be driven by cementing tin foil to one end. An alternating voltage of variable frequency combined with a polarizing voltage is connected to the condenser thus formed. The rod vibrates when its characteristic frequencies resonate with the driving voltage. This vibration can be detected by ear, or by amplifying the piezoelectric voltage set up across a small Rochelle salt crystal in contact with the rod. Dynamic values of E were obtained for the series of rock specimens measured statically by Zisman. Agreement is good for compact rocks like diabase, while dynamic E is higher than static E for granite, gneiss and other rocks. The dynamic values for Quincy granite and Sudbury norite agree with those obtained by Leet from explosion wave velocities in the same rocks.

63. Surface Pressures and Potentials of Monomolecular Films of Long Molecules: Hydroxy Decanoic Acid Polymers. William D. Harkins, Everett F. Carman and Herman E. Ries, Jr., *University of Chicago.*—Remarkable relations are exhibited by films of linear polymers of the formula $HO[(CH_2)_9COO]_xH$ with molecular weights to 25,200 as prepared by Drs. Carothers and van Natta. The molecules lie flat on the surface and exhibit the following characteristics for the condensed films at 3 dynes per cm of pressure: (1) Thickness 4.5A; (2) distance between centers of adjacent chains approximately the same as the

thickness of the film; (3) apparent vertical cross section of the molecules 20 sq. A, or about the same as the horizontal cross section of molecules oriented vertically; (4) compressibility very large, independent of molecular weight and of value 0.045 per dyne; (5) the surface potential increases 13 percent less rapidly with pressure than the density of the film; (6) at zero pressure the molecular area is very large (10,400 sq. A) for the molecules of molecular weight 25,200.

64. The Heat-Flow Calorimetric Method. W. P. WHITE, *Geophysical Laboratory, Carnegie Institution.*—This method belongs to the group where the heat is known and the temperature change produced by it is to be found. Since 1900 the heat has been more often produced electrically, but the older heat-flow method, where the heat passes directly from the warmer surrounding walls to the calorimeter, still has advantages. In the modern form of this method these walls are usually heated electrically, giving continuous runs over wide temperature ranges very simply. The whole procedure is really elementary, but the precision has sometimes been so low that an investigation seemed worth while. The chief difficulty has usually been lack of uniformity in the surrounding temperature, which falsifies the thermal head measurement on which knowing the heat depends. A precision of at least 0.02° in this measurement will usually be necessary for 1 per mille final precision. Stirred baths can give this; well-distributed heaters alone usually not. Convection greatly complicates the heat determination; it can be practically eliminated by making the air gap small, say 5 mm. To obtain the precision made possible by the above features the heat-conducting partitions inside the calorimeter and the thermels must be more effective than they have sometimes needed to be.

65. The Coefficient of Linear Expansion for Stretched Rubber Bands at Room Temperatures. MILTON L. BRAUN, *Catawba College.*—A number of vulcanized rubber bands of the same composition were suspended so as to support respective loads of 350, 550, 750 and 1000 g. The lengths of the bands at plus and minus room temperature deviations from 27.0°C were observed from day to day. The coefficient of expansion, $\alpha = (\Delta l/\Delta t)/l_{27}$, was found to vary with time and with load. It has been shown that the length of a loaded band varies continuously with time,[1] but this phenomenon is insufficient to account for the change with time in the coefficient. That is to say, $\Delta l/\Delta t$, as well as l_{27}, varies with time but not in the same manner. For the first three loads $|\alpha|$ decreased both with time and with load, the range being -0.00244 at the first time-region of about 20 days (with an elongation of 207 percent), to -0.000435 at 6 months (when the elongation was 589 percent). For the kilogram load, however, α was found to increase instead of decrease with time, its numerical value being more than 10 percent greater in the neighborhood of 3 months than at 3 weeks, and more than 30 percent greater at 6 months, the increase in the coefficient being about ten times that of the corresponding increase in elongation. The coefficient seems to be independent of the sign of Δt.

[1] M. L. Braun, *The Extensibility of a Rubber Band as a Function of Time*, paper presented at the sixth annual meeting of the Society of Rheology, Philadelphia, October 19, 1934.

66. Scattering of Alkali Atoms in Various Gases. S. ROSIN, *Columbia University.*—The investigation previously reported of the scattering of narrow atomic beams of sodium and potassium in the several gases employed, has been extended to include the remaining alkalis. With geometrical conditions such that changes in the direction of motion of the beam atoms of more than one minute of arc were counted as collisions, the mean free paths of the different alkali atoms in the various gases were determined. Table I gives the effective collision radii thus calculated.

TABLE I. *Collision radii in Angstroms.*

Gas	Lithium	Sodium	Potassium	Rubidium	Caesium
H_2	6.21	7.01	7.47	7.38	7.54
D_2	6.32	7.62	8.54	8.24	8.34
He	5.82	6.44	7.25	6.96	7.18
Ne	6.18	8.24	9.10	9.23	9.56
A	9.83	11.3	13.6	13.5	13.45

Interesting results of the extended investigations include the disappearance of the difference in collision radius of hydrogen and deuterium when lithium is employed as the parent beam, and the constancy within experimental error (5 percent) of the collision radii of the heavier alkalis with each of the gases employed. Another result of the experiment is that the beam after passing through the scattering gas has the same form as the original unscattered beam. This implies that the total collision cross section is finite, in agreement with quantum theory, but in sharp disagreement with classical prediction.

FRIDAY MORNING AT 10:00 O'CLOCK

Bureau of Standards

Chemistry Building, Lecture Room

67. Deep Terms in Ions of the Isoelectronic Sequence Cl I to Mn IX. S. G. WEISSBERG AND P. GERALD KRUGER, *University of Illinois.*—The $3p^5\ ^2P^0_{3/2\ 1/2}$ deepest terms of this sequence combined with $3p^44s\ ^2P_{3/2\ 1/2}$ to give a very strong characteristic P^0P multiplet. With the aid of constant second difference graphs, of the displacement of radiated frequencies (Kruger and Shoupp, Phys. Rev. **46**, 124 (1934)), it has been possible to identify the P^0P multiplet of Ca IV from E. Ekefors (Inaugural Dissertation, Verlagsbuchhandlung Julius Springer in Berlin, 1931) and of Ti VI and Mn IX from data on our spectrograms, which were taken with a twenty-one foot grazing incidence

TABLE I. *Values of deep terms and ionization potentials.*

Ion	$3p^5\ ^2P_{3/2}$ cm^{-1}	Ion. potential (volts)	First diff. (volts)	Second diff. (volts)
Cl I	104,991	12.952		
			14.76	
Ar II	224,721	27.722		4.1
			18.8	
K III	377,000	46.5		4.4
			23.2	
Ca IV	565,000	69.7		4.1
			27.3	
Sc V	(786,400)	97.0		4.0
			31.3	
Ti VI	1,040,000	128.3		3.9
			35.2	
V VII	(1,325,000)	163.5		4.0
			38.0	
Cr VIII	(1,640,000)	202.		4.0
			42.0	
Mn IX	1,983,000	245.		

vacuum spectrograph. Table I gives the value of the deepest term as computed from the $(v/R)^{\frac{1}{2}}$ law and the corresponding value of the ionization potential in volts. The values in parentheses are interpolated. The radiated frequencies of the lines identified as the P^0P multiplets are given in Table II.

TABLE II. *Radiated frequencies of the P^0P multiplet.*

	$^2P^0_{1/2}-{}^2P_{3/2}$	$^2P^0_{1/2}-{}^2P_{1/2}$	$^2P^0_{3/2}-{}^2P_{3/2}$	$^2P^0_{3/2}-{}^2P_{1/2}$
Ca IV	(4?) 295,135	(4) 297,129	(5) 298,201	(0). 300,175
Ti VI	(2) 496,758	(8) 500,608	(30) 502,566	(2) 506,436
Mn IX	(881,700)	(4) 889,585	(7) 892,498	(900,383)

68. Hyperfine Structure of Y II Lines. C. N. CHALLACOMBE AND P. GERALD KRUGER, *University of Illinois.*—The yttrium spectrum has been excited in a water-cooled hollow cathode lamp of the vertical type by using argon as the exciting gas. The lines of the $4d^2\ ^3F_{432}-4d5p\ ^3D_{321}$ multiplet have been examined for hyperfine structure with a Fabry-Perot etalon inserted between the collimating lens and the prisms of a three-prism Steinheil spectrograph. A separation of 3, 4, 5, 8, 10, 12, 20 and 40 mm has been used between the etalon plates. From the observed components it is possible to deduce the hyperfine term splittings as shown in Table I. The splitting of the terms $^3D_1$ and $^3F_2$

TABLE I. *Hyperfine term splitting in terms of Y II.*

Term	Splitting (cm^{-1})	Term	Splitting (cm^{-1})
$^3D_3$	+1.15	$^3F_4$	+1.18
$^3D_2$	+0.23	$^3F_3$	+0.38
$^3D_1$	(−0.67)?	$^3F_2$	(−1.05)?

are only estimates since the weakest hfs component for this transition has not been found. The data do indicate, however, that the hfs terms are inverted for $^3D_1$ and $^3F_2$. A value of the nuclear moment $i=\frac{1}{2}h/2\pi$ is in agreement with these data.

69. Wavelength Measurements in the Spectra of the Neodymium Arc and the Standard Pfund Iron Arc. GEORGE R. HARRISON AND WILLIAM W. BARTLETT, *Massachusetts Institute of Technology.*—Over 100 spectrograms have been taken on 2×20-inch plates in the region 6000–2200A, at dispersions averaging 0.4A/mm and resolution of about 200,000. Highly purified neodymium oxide from two sources (Hilger Rolla and Hilger Prandtl) was burned in silver and in graphite arcs, and a standard Pfund iron arc spectrum was superposed. The plates are being measured with hand setting but automatic wavelength reduction and recording on the Institute's automatic plate measuring engine (Harrison, Phys. Rev. **45**, 760 (1934)). The International Secondary Iron Standards are being used, and a redetermination is being made of the tertiary iron standards, particularly of the weaker lines, in terms of these. The internal consistency of the neodymium wavelengths, and the fits found in a tentative quadratic array of Nd II terms, indicate that most of the lines are being measured correctly to 0.001A. It is expected that the entire set of plates will be measured several times with automatic setting.

70. Atomic Absorption Spectra of the Rare Earths. FRED W. PAUL, *Massachusetts Institute of Technology.* (*Introduced by George R. Harrison.*)—A modified King electric furnace, charged with various rare earth oxides, has been used to observe the absorption spectra of cerium, neodymium, samarium, europium, dysprosium, holmium, thulium, and ytterbium in the region 9000 to 2900A, with a concave grating giving dispersion of 2.5A/mm. 550 lines have been observed in the absorption spectrum of Ce between 3500 and 8900A, and in Sm 880 lines have been observed between 2900 and 8300A. More than 300 lines have been identified as arising from Nd, and as many from Tm. Eu and Yb give rise to very simple absorption spectra, and impurities of either in other substances are very evident in absorption. Only the strongest lines of Dy and Ho have been observed in absorption. In general the absorption spectra confirm the line types as given by King's temperature classification in that, of those lines which are absorbed, the Class I lines are absorbed much more strongly than Class II lines, which are in turn stronger than Class III lines; and give additional data in that only those lines of each class which involve the lowest levels appear in absorption. The data obtained are being used in the laboratory program of analysis of rare earth spectra.

71. The Spectra of Phosphorus, P II, P III, P IV. HOWARD A. ROBINSON, *Massachusetts Institute of Technology.*—Spectrograms have been taken using a Geissler tube discharge in phosphorus vapor from 500A to 7000A. The present analyses summarized in Bacher and Goudsmit are substantially confirmed. A fairly complete set of singlets has been found in P II together with intercombinations and a few high series terms in the triplet system. Most of the remaining doublets predicted by the Hund theory have been located in P III together with possible intercombinations. Some changes are suggested in the higher series terms. A few new levels have been located in P IV. In this spectrum the intercombinations are fairly numerous and show that Bowen's estimate for the low $3s3p\ ^3P$ term is too high by 324.3 cm^{-1}.

72. An Extension of the Thallium II Spectrum. CECIL ELLIS AND RALPH A. SAWYER, *University of Michigan.*—The spectrum of Tl from the hollow cathode discharge tube has been photographed in the region from 600A to

9200A. Knowledge of the first spark spectrum has been extended by the classification of 150 new lines of from moderate to strong intensities, which locate 26 new levels and also fill in missing transitions in the existing system. The new terms include members up to $n=11$ of the s, p and d series, the first two members of the g series, as well as 5 new odd levels which probably belong to the $5d^96s^26p$ configuration. Large hyperfine structure was observed in many of the new lines which, while not accurately investigated, appears to agree with known hfs separations in this spectrum.

73. The Spectra of Argon and Krypton in the Extreme Ultraviolet. J. C. BOYCE, *Massachusetts Institute of Technology.*—Continuing the investigation of rare gas spectra with the Carnegie Institution of Washington vacuum spectrograph located in this laboratory, considerable extensions have been made in the extreme ultraviolet spectra of argon and of krypton. Revisions have been made in the limit assignments of the terms in de Bruin's analysis of A II. A number of triplet terms have been added to those already known for A III and the low odd term and most of the intermediate even terms of the doublet system of A IV have been discovered. Additional confirmation is thus obtained for the identification of the nebular lines λ4711.4 and λ4740.2 as due to the nebular type of forbidden transition in A IV. Two multiplets of A V have been found. In krypton 31 additional extreme ultraviolet lines from Kr II have been identified bringing to 82 the total number of known lines in this region assigned to this spectrum. 138 lines of Kr III have been identified in collaboration with C. J. Humphreys' analysis of the longer wavelength range of the third spectrum of this gas.

74. The Third Spectrum of Krypton. C. J. HUMPHREYS, *Massachusetts Institute of Technology.*—The spectrum characteristic of the Kr^{++} ion has been selected from the various krypton spectra excited in a Geissler tube discharge. The distinction between lines of Kr III or higher spark spectra and those of Kr II is based on the partial or complete suppression of the former by inductance in the discharge circuit. Wavelength measurements, based mainly upon observations with the Rowland grating at the Bureau of Standards, extend from λ2100 to λ7400. A total of 369 lines has been classified arising from 88 levels of Kr III. The low states of Kr^{++} are ^3P, ^1D and ^1S, due to the $4s^24p^4$ configuration. The higher excited states are built upon the ^4S, ^2D and ^2P states of Kr^{+++} by the addition of ns, np or nd to the normal $4s^24p^3$ configuration. All but 8 of the 76 levels comprising the first excited states have been found. The connection between these and the low states has been established by use of J. C. Boyce's extreme ultraviolet data. Numerous inter-limit combinations have permitted precise evaluation of relative term values. Calculations based on the $4p^3(^4S)ns^3S^0$, and $4p^3(^4S)nd^3D^0$ and $^5D^0$, series have led to an estimated value of 298,020 cm^{-1} for the lowest $4p^4(^4S)^3P_2$ level, corresponding to an ionization potential of 36.8 volts.

FRIDAY AFTERNOON AT 2:00 O'CLOCK

Bureau of Standards

East Building, Lecture Room

75. Production and Absorption of Cosmic-Ray Showers. R. H. WOODWARD AND J. C. STREET, *Harvard University.*—A group of Geiger-Müller counters has been arranged to investigate the production of showers. A slight modification of this arrangement has been used to measure directly the absorption of the shower particles. The shower production curve for lead obtained with this arrangement is in agreement with similar data reported by numerous observers but the directly observed absorption of the shower particles is quite different from the usual assumption that these particles have a penetrating power of about 1.5 cm of lead (thickness for maximum observed number of showers). The shower particles are absorbed approximately exponentially and fall to one-third value in three mm of lead. Using this absorption coefficient for shower particles and the observed rate of shower production, we have corrected for self-absorption of shower particles in the scattering material to obtain the true (or total) rate of shower production. The derivative of this rate of production with respect to the thickness is presumably proportional to the intensity of the shower producing radiation. It is found that the intensity of the producing radiation rises to a peak at one cm of lead two or three times its initial value and then decreases approximately exponentially attaining the initial value at about seven cm.

76. On the Longitude Effect of Cosmic Radiation. M. S. VALLARTA, *Massachusetts Institute of Technology.*—If the equivalent magnetic dipole describing the earth's magnetic field at large distances is placed at the magnetic center of the earth as calculated by Schmidt, instead of at the center of the geoid, then the theory of the latitude and azimuthal effects developed by Lemaitre and Vallarta also accounts for the longitude effect found by Clay, Van Alphen and Hooft and, independently, by Millikan and Neher. Further, if the distribution function of magnetically deflectable particles capable of reaching the tropical belt is substantially an exponentially decreasing function of their energy, the theory agrees quantitatively with experiment; except for the measurements made by Millikan and Neher on the steamer lane from Honolulu to Sydney-Melbourne.

77. The Corpuscular Theory of the Cosmic Rays. W. F. G. SWANN, *Bartol Research Foundation.*—An exponential law of absorption results from the assumption that the

measured intensity is that of secondaries which perpetuate the directions of the primaries and are produced all along the paths thereof in amounts proportional to the primary energies. It is maintained that this approximation provides the component of the radiation which, by analysis of the absorption curves, represents the greater part of the measured intensity. The incorporation of principles which cause the range or intensity of production of secondaries, and so the rate of absorption of energy per unit length of primary path, to increase with energy less rapidly than linearly gives a softening of the individual rays with decrease of energy such as is necessary to account for the variation of east-west asymmetry with altitude and latitude. The assumption of a range of energies in the rays entering the atmosphere, necessary for the latitude and directional effects, then provides for the story of hardening in passage through the atmosphere. The assumption that the production of the secondaries in lead increases with primary energy more rapidly than linearly serves, in its development, to correlate a variety of phenomena concerning the effect of altitude, latitude, and direction of primary rays, in the production of showers.

78. A Study of Oxygen Isotopes. WALKER BLEAKNEY AND J. A. HIPPLE, JR., *Princeton University.*—During the last year over a hundred samples of oxygen have been analyzed with the mass spectrograph. All the values for the ratio $O^{16} : O^{18}$ cluster around the number 500. These samples came from a variety of sources prepared in a number of different ways. A few came from meteorites. Samples of commercial oxygen were found to vary in isotopic concentration from tank to tank. This suggests that refinements of some of our atomic weight determinations would have little meaning without an isotopic analysis at the same time. The fractionation of the oxygen isotopes produced by the electrolysis of water was measured and found to be about 1.01. This result is in good agreement with the recent work of Johnson but disagrees with the earlier work of Washburn and the Bureau of Standards group.

79. The Production of Helium of Mass Three? H. D. SMYTH, G. P. HARNWELL, W. BLEAKNEY AND W. W. LOZIER, *Princeton University.*—In letters to the *Physical Review* last summer we reported evidence for the production of helium of mass three by impact of canal rays of deuterium in deuterium. Mass spectrograph analyses of the treated samples showed ions of mass three appearing at an ionization potential approximately that of helium. Further evidence was the detection of helium lines in the spectrum of a sample of the treated gas. Doubt has now been cast on interpretation of the mass spectrograph evidence by experiments on the rate of diffusion of the gas producing the mass three peak. It has been found to diffuse more slowly than ordinary helium. Another explanation of the mass three ion is to assume it a secondary product of ionization of heavy methane (CH_2D_2 or CH_3D) present as a small impurity. This had been considered at the time of the original experiments but discarded as of negligible probability. A study of ionization processes in methane made this winter in our laboratory shows the explanation hardly possible. The spectroscopic results remain entirely unexplained. Consequently we find ourselves in the position of having apparently good evidence both for and against the production of helium three in these experiments. Since we are progressing out of the dilemma very slowly we feel we should report the present state of the problem unsatisfactory though it be.

80. The Hyperfine Structure and Nuclear Magnetic Moment of Caesium. R. K. STRANATHAN AND L. P. GRANATH, *New York University.*—The hyperfine structure of the lines λλ8761, 4593, 4555, 3889 and 3877 in the arc spectrum of caesium has been investigated using a Fabry-Perot etalon. The $g(I)$ values were calculated from Goudsmit's formulas, using Z_i values for the P states as obtained from fine structure data. (Table I.) The interval for the

TABLE I.

State	Interval factor	Percent error	Z_i	$g(I)$
$6^2S_{\frac{1}{2}}$	0.0767	0.2	55	0.76
$6^2P_{\frac{1}{2}}$	0.00925	3.	49	0.68
$7^2P_{\frac{1}{2}}$	0.00331	4.	49	0.75
$8^2P_{\frac{1}{2}}$	0.0017	20.	48	0.86

$6^2P_{\frac{1}{2}}$ level was measured directly, while the separations for the unresolved $7^2P_{\frac{1}{2}}$ and $8^2P_{\frac{1}{2}}$ states were obtained from the difference between the doublet separations of the two lines involved in each case. The $g(I)$ values calculated from the P states agree within the limits of experimental error. The experimental error in the interval factor for the $6^2S_{\frac{1}{2}}$ state is extremely small; however it is unlikely that the theoretical formula is as accurate for this state. The $g(I)$ value appears to be 0.72.

81. Nuclear Spin and Magnetic Moment of Li^7. M. FOX, S. MILLMAN AND I. I. RABI, *Columbia University.*—The nuclear spin and hfs separation, $\Delta\nu$, of the normal $^2S_{\frac{1}{2}}$ state of Li^7 has been determined by the method of neutral atomic beams previously applied to determine similar properties of K^{39}. The value obtained for the spin is 3/2, in units of $h/2\pi$, in agreement with the results from hyperfine structure and alternating intensities in band spectra, but not with the results of Ladenburg and Levy. The value of $\Delta\nu$ was found to be 0.0262 cm^{-1}. Using the modified Goudsmit formula we obtain a value of 3.14 nuclear magnetons for the magnetic moment of the Li^7 nucleus. The value for the nuclear magnetic moment obtained by Granath from work on hyperfine structure lines of singly ionized lithium, using the theory of Breit and Doerman, is 3.29. Although the difference between the two values is somewhat greater than the experimental error, it is strikingly good in view of the theoretical foundation of the modified Goudsmit formula. The question whether this difference between the two values of the nuclear magnetic moment is real must await further theoretical consideration.

82. On the Nuclear Spin and Magnetic Moment of K^{41}. S. MILLMAN, M. FOX AND I. I. RABI, *Columbia University.*—In the course of the work on K^{39} previously reported

(Phys. Rev. **46**, 320 (1934)) sufficient resolution was obtained to resolve a peak due to K^{41} by the method of "zero moments" (Phys. Rev. **46**, 707 (1934); **47**, 334 (1935)). The existence of this peak proves that the nuclear spin of K^{41} is greater than 1/2, in units of $h/2\pi$. From the value of the field at which this peak occurs we can place the ratio of the nuclear magnetic moment of K^{41} to that of K^{39} between the limits of 0.42 and 0.88 depending on the spin of K^{41}.

83. The Production of X-Radiation by Very Fast Electrons. EDWIN MCMILLAN, *University of California.*—The theoretical calculation by Bethe and Heitler[1] of the rate of production of radiation by fast electrons indicates that this becomes a very probable process at energies of several million volts. The availability of strong sources of artificially radioactive substances has made it possible to test the prediction experimentally. Active phosphorus (P^{32}) gives beta-particles with a maximum energy of 1.8 mv, and no gamma-rays, and has a very long half-life; it is therefore admirably suited for this experiment. The radiation emitted when these beta-particles are stopped by paraffin, aluminum and lead were observed by an electroscope. The intensity of the radiation from lead corresponds to about one quantum per 25 beta-particles; it is absorbed to about 1/4 in 1 mm of lead and to 1/8 in 2 mm of lead. The intensity of the radiation when the beta-particles are stopped in aluminum and paraffin is respectively 1/6 and 1/12 as great as in lead, being thus proportional to the atomic number as required by the theory. Chlorine activated by deuteron bombardment gives an active body with very energetic (4.5 mv) beta-particles, but these are accompanied by gamma-rays (about 1/4 quantum per disintegration) increasing the difficulty of studying the secondary radiations. It is possible to show, however, that they are 2 or 3 times as intense as those produced by the phosphorus beta-particles, and considerably harder.

[1] Bethe and Heitler, Proc. Roy. Soc. **A146**, 83 (1934).

FRIDAY AFTERNOON AT 2:00 O'CLOCK

Bureau of Standards

Industrial Building, Room 301

84. Oscillographic Study of Overvolted Discharges. J. W. FLOWERS, *University of Virginia.* (*Introduced by J. W. Beams.*)—The initiation of discharges in effectively ion-free gases (Phys. Rev. **46**, 338 (1934)) has been studied by means of an oscillograph using a time resolving power of about 6×10^{-9} sec. per mm on the film. The potential is applied in a few hundredths of a microsecond to a sphere gap (also point and plane) in an inclosure containing dry, dust-free air. Under these conditions potentials of more than 10 times static breakdown values can be applied. For potentials much exceeding this the breakdown occurs immediately on reaching a value where field emission might be expected. For values slightly less than this time lags as long as a half microsecond are observed. When the discharge occurs at these high field strengths the rate of fall of potential in the initial stages is very much faster than for ordinary breakdown. The breakdown potential for spherical electrodes has been traced from atmospheric pressure down to the vacuum spark stage and found to be relatively independent of the pressure until the electron mean free path has reached a value comparable to the electrode spacing. It is believed that these discharges are initiated by field emission.

85. Electrical Conductance of Short Cold-Metal Gaps in Air. ROBERT E. FEARON, *University of Pittsburgh.* (*Introduced by E. Hutchisson.*)—The conductance of sphere-plane gaps, or their equivalent, for potentials between 0.0001 volt and two volts was determined in air at atmospheric pressure for gap widths between 5000A and 100A. Radii of curvature for the spherical electrodes were 7 meters, 14 cm and 25 microns. Appreciable conduction for gaps of the type used appears to be caused by a layer of fine dust between the surfaces and by imperfections in them. Results obtained with intermediate radius of curvature of the spherical electrode were more erratic than those obtained with a spherical electrode of very large radius of curvature. Since the area of close approach is larger in the latter case, this result is to be expected if the conductance is caused by the total effect of a large number of dust particles. The increasing abruptness of the change of conduction with respect to gap width for curves representing successive experiments indicates the eventual formation of conducting prominences on the surfaces during the course of the experiments. This occurrence is more marked for electrodes of smaller radius of curvature.

86. A Cloud Chamber Study of the Initiation of Ionization in Spark Discharge. CHARLES D. BRADLEY, *University of Virginia.*—Using the method described recently for photographing the initial ionization in spark discharge (Bradley and Snoddy, Phys. Rev. **47**, 541 (1935)), a study of the initiation of ionization between a small sphere and a plane in a cloud chamber has been made with the electrodes irradiated with the ultraviolet radiation from an iron arc. A short potential impulse of less than 10^{-7} sec. duration is applied to the electrodes at the end of the expansion of the chamber and the resulting ionization photographed. Discharges requiring a maximum field intensity of the order of 10^5 volts/cm to start during this impulse, without irradiation, are started by maximum fields of the order of 5×10^4 volts/cm with the electrodes irradiated. This starting potential is not markedly affected by whether the small electrode is the anode or the cathode during the impulse. However, photographs of the ion distribution show that the propagation of ionization is

faster when the small electrode is the anode. This propagation may therefore determine the real time lag of discharges in nonuniform fields.

87. Products of Ionization in Methane. J. A. HIPPLE, JR. AND WALKER BLEAKNEY, *Princeton University.*—An investigation has been made of the ionization products in methane by the usual mass-spectrographic method. The following ions have been observed: CH_4^+, CH_3^+, CH_2^+, CH^+, C^+, H_2^+ and H^+. Pressure, electron current and pumping speed variations show that all of these are primary products with the exception of H_2^+ which was too small to study. The H_2^+ is approximately 1/10,000 the size of the CH_4^+ peak and is possibly an impurity. The ionization probability curves that have been obtained are of the usual shape. The percentage of the total ionization due to each ion is independent of the pressure over a wide range and independent of the electron velocity from 30 to 100 volts. Using argon for calibration appearance potentials for CH_4, CH_3, CH_2, CH, C, H, have been observed at 13.7, 14.7, 15.7, 23, 27 and 31 volts, respectively. The use of Ne, CO and H_2 for calibration yields values in substantial agreement with the above. No negative or doubly-charged ions have so far been observed. A preliminary analysis of CD_4 and CHD_3 reveals characteristics similar to those outlined above for CH_4.

88. Ionization of Neon and Argon by Singly Charged Magnesium Ions. J. C. MOUZON AND NEWELL H. SMITH, *Duke University.*—The efficiency of ionization (the number of electrons ejected per initial positive ion per cm path per mm pressure) by singly charged magnesium ions is compared with that of singly charged sodium ions to obtain further information on the parts played by mass and electron configuration in the ionization process. The efficiency of the former is about 60 percent of that of the latter in both gases. Data on the mean free path of magnesium and sodium ions in the two gases must be had before a quantitative comparison of the results can be made. If one assumes the mean free path of magnesium ions greater than that of sodium ions, the results indicate that the chance of ionization on a single impact may be approximately the same for both ions.

89. New Measurements on the Lifetimes of Excited States in Neon. EUGENE W. PIKE, *Scott Paper Co., Chester, Pa.*—Penning has shown that illumination of a Townsend discharge in neon with light from a positive column in neon reduces the concentration of excited atoms in the former discharge. From his data, the quantitative relation of the concentration to the illumination intensity is derived directly. This relation also can be deduced from existing data on line contours, line intensities, etc., and a comparison yields these values for the mean lifetime of excited atoms in pure neon; $s_5(^3P_2)$ metastable state, 1/(500×pressure in mm Hg); mean of s_2 and s_4 resonance states, 1/(15,000×pressure). Comparison values by absorption methods for the metastable state are: 1/(1100 ×pressure) and 1/(125×pressure). Weizel has suggested that inelastic collisions between two atoms are essentially transitions between electronic levels of the quasi-molecule formed of the two impacting atoms, and that the usual quantum rules apply. On this basis, metastable neon atoms can return to the normal state only by direct radiative transitions during collision. The "coupling broadened" resonance lines of Langmuir and Found also find theoretical backing.

90. The Diffraction of Electrons by Thin Films of Iron Oxides and Hydrates. NEWBERN SMITH, *University of Pennsylvania. (Introduced by Raymond Morgan.)*—Diffraction patterns have been obtained by the transmission of electrons through thin films of iron oxide and of ferric oxide monohydrate. The films removed electrolytically from iron heated in air had the crystal structure common to both ferrosic oxide (Fe_3O_4) and ferromagnetic ferric oxide (γ-Fe_2O_3). The evidence indicates that the oxide was probably Fe_3O_4. This disagrees with U. R. Evans, who believed the films to be of nonmagnetic ferric oxide (α-Fe_2O_3). The crystals in the films were at least 200A on a side, and showed no preferred orientation. The films of ferric oxide hydrate were prepared by the action of ammonia on the surfaces of solutions of iron salts. The patterns of the γ-hydrate (γ-FeOOH) films showed the presence of some oxide, and the diffuseness of the rings indicated peculiarities of crystal structure. The dehydration of these films gave films of γ-Fe_2O_3, with a lattice constant somewhat larger than that of the γ-Fe_2O_3 obtained by the oxidation of the Fe_3O_4 films, and with crystals of colloidal dimensions (~20A). On heating, these crystals grew to over 200A before the γ-Fe_2O_3 changed into the rhombohedral α-Fe_2O_3. The α-hydrate films were normal in structure, and gave α-Fe_2O_3 on dehydration.

FRIDAY AFTERNOON AT 2:00 O'CLOCK

Bureau of Standards

Chemistry Building, Lecture Room

Paper No. 98 will be read by title.

91. The Spectra of Helium by High Frequency Excitation. MAX PETERSEN AND HOWARD CARL, *Lehigh University.*—The spectra of helium, atomic and molecular, have been studied under a variety of conditions of pressure, purity and electrical excitation to ascertain whether the enhancement of certain singlet lines, notably λ5015A, is accompanied by any similar behavior of the singlet molecular spectrum. The helium was excited in a quartz

tube 5 cm in diameter, 75 cm long. It was continuously circulated for purification through a chabazite trap and a misch-metal arc chamber. Excitation, by various electrical power sources, was always through external electrodes, usually using the "electrostatic" field. The relative enhancement of λ5015 was found to depend less on the high frequency of the excitation than on other conditions of the discharge, similarly the singlet band spectrum and the continuous. A survey of the variously observed spectra seems to indicate that in the band spectrum of helium there is not such a diversity of excitation functions as Hanle found in the atomic terms.

92. Extension of the Rh I-Like Isoelectronic Sequence to the Spectrum of Ag III. W. P. GILBERT, *Cornell University.*—The vacuum spark spectrum of silver has been photographed and measured in the region 500 to 2600A. To assist in the identification of Ag III lines, the spectrum of silver from the hollow cathode discharge in an atmosphere of helium was photographed in the same region. A spark gap placed in series with the Schüler tube served to bring out the Ag III lines in the spectrum of the discharge. With the already reported separation of 4607 cm^{-1} for the ground state, $4d^9\ ^2D_{2\frac{1}{2},\ 1\frac{1}{2}}$, as a basis and by employing the above method of distinguishing the radiations, it has been possible to establish 55 terms originating from the $4d^9$, $4d^8 5s$, and $4d^8 5p$ configurations and to classify a total of 257 lines. Approximate term values have been obtained by extrapolation of a Moseley diagram for the elements of this sequence. The value obtained for the lowest state of Ag III with respect to the $4d^8\ ^3F_4$ state of Ag IV is 291,256 cm^{-1}, which corresponds to an ionization potential of 35.9 volts.

93. The Energy Levels of the Rare Gas Configurations. C. L. BARTBERGER, *Allegheny College.* (*Introduced by C. W. Ufford.*)—The energy levels of the $n'p^5np$ configuration of the rare gases were calculated for low values of n from the secular equations involving the electrostatic and spin-orbit interactions. For these low values of n, the electrostatic interaction between the levels having different levels of the ionic doublet as parents becomes appreciable. The radial integral parameters were found from the observed levels by a graphical method. The results obtained in this way agree with observed values on the average about as do the levels found recently by Shortley for the $2p^5\ 3p$ configuration of neon. In some cases the absolute magnitudes of the errors are small enough so that it is hoped to obtain reliable values for the transition probabilities.

94. Zeeman Effect in Diatomic Molecular States Having L-Uncoupling. JULIAN K. KNIPP, *Harvard University.*—A theoretical investigation has been made of the behavior of Zeeman levels in molecular states intermediate between Hund's case b' and case d', which are the limiting cases in the passage from a state in which the orbital angular momentum of the electrons is quantized along the axis of figure of the molecule to one in which it is quantized along the axis of rotation of the nuclei. Zeeman patterns for the $3d$ and $4d$ complexes ($L=2$) of the helium molecule have been calculated and curves obtained for the variation of the overall widths with K, the rotational quantum number. For small K the energies are near the case b' values, but as K increases a breaking away occurs which results in their approaching the case d' energies. When the state in the limiting case d' has the electronic angular momentum quantized anti-parallel to the nuclear rotation, a crossing over of the magnetic energy curves takes place with the passage through a state in which the molecule is relatively insensitive to the field. This crossing over occurs between K equal to 4 and 8 for the Δ states of the helium molecule considered (magnetic field 30,000 gauss). For the state correlated to the limiting case of zero component along the axis of rotation, a crossing and recrossing can take place.

95. Orbital Valency According to an Extended Heitler-London Method. GERTRUD NORDHEIM, *Purdue University.* (*Introduced by K. Lark-Horovitz.*)—An extension of the Heitler-London theory of chemical bond is developed so as to take into account not only the ground states but also the lowest excited states of the composing atoms (their excitation energies included). It can be shown that possible molecular states of the same symmetry-character (arising from different atomic terms) may interact strongly. In this way the concept of orbital valency and the different behavior of the ground states of diatomic molecules, which are not necessarily those of lowest multiplicity (triplet terms of C_2 and O_2), can be satisfactorily described. The directional properties of valency in polyatomic molecules (f.i. tetrahedral structure of CH_4, the rigidity of the double bond) can also be explained by this combination method considering the degeneration of the atomic P and D levels.

96. The Normal Helium Atom. J. H. BARTLETT, JR., J. J. GIBBONS, JR. AND C. G. DUNN, *University of Illinois.*—It is proposed to test the goodness of approximate wave functions by means of a least-squares criterion. A root-mean-square energy deviation is defined, and calculated to be 3.5 volts for the six-term function of Hylleraas (Zeits. f. Physik **54**, 347 (1929)). It can be proved that there is no series in ascending powers of the variables r_1, r_2, and r_{12} which is a formal solution of the Schrödinger equation. It is possible, however, to find formal solutions for the region $r_1<r_2$ (and similarly for $r_1>r_2$) which are series in descending powers of r_2 and in ascending powers of $z=\cos\theta$, where θ is the angle between r_1 and r_2.

97. Intramolecular Forces Between Bound Atoms. WM. ALTAR, *The Pennsylvania State College.* (*Introduced by William R. Ham.*)—The analytic method of Lennard-Jones and Pike (Trans. Faraday Soc. **30**, 830 (1934)) is extended and refined. Particularly, a study is made of the forces acting between the two CH_2Cl groups in 1,2-dichloroethane, and between the CHCl groups in dichloroethylene. The presence of repulsive forces between bound Cl atoms at distances as large as 4.4A is established, which is at variance with current views though well in line with theoretically derived curves for the potential of interatomic interaction. It is shown how this result can be coordinated

with seemingly conflicting evidence obtained from the thermal equilibrium ratio r of the two isomers of dichloroethylene (63 percent cis at 300°C). This is done by discussing the temperature variation of r which one must expect when considering the differences between the entropies, rotational and vibrational, of the two isomeric forms; the zero-point energy of each form, particularly, constitutes an important contribution to the respective heat of formation, and is apparently considerably larger for the transform of dichloroethylene.

98. Gravitational and Electromagnetic Mass in the Born-Infeld Electrodynamics. B. HOFFMANN, *University of Rochester.*—In the general spherically symmetric field of the Born-Infeld theory, the gravitational part contains an integration constant m in the form $-2m/r$. This leads to an infinity at $r=0$. If it is postulated that only fields that are nowhere infinite are allowed, the constant m must be taken as zero. It is shown that this makes the gravitational mass of the electron correspond to its electromagnetic mass, and that this implies that the gravitational mass cannot be negative, which is not the case in the usual relativity theory. The alternative Born-Infeld field equations may be considered in the light of the above postulate. It turns out that the $G\neq 0$ field equations permit the existence of isolated magnetic poles, while the $G=0$ field equations, since they would lead to an infinity in the field of such a pole, deny that such a pole can exist.

SATURDAY MORNING AT 10:00 O'CLOCK

National Academy of Sciences

Auditorium

99. Extra Negative Term in the Incoherent Part of the Diffuse Scattering from Neon-Like Crystals. G. E. M. JAUNCEY AND J. H. DEMING, *Washington University.*—Using the technique developed by Jauncey and Claus (Phys. Rev. **46**, 941 (1934)) we have measured S values for NaF for primary rays whose spectral distribution showed a maximum at $\lambda=0.48$A. The results for various scattering angles were: 17°, 1.01 (0.96, 1.09); 20°, 1.07 (1.04, 1.15); 25°, 1.11 (1.12, 1.20); 30°, 1.12 (1.12, 1.17); 40°, 1.08 (1.10, 1.12); 55°, 1.03 (1.05); 90°, 0.88 (0.93). The quantum-mechanical values including the Waller-Hartree extra negative term are shown as the first number in parenthesis, the second number (where there is such) not including this negative term. The inclusion of the negative term brings better agreement between the theoretical and experimental values. Measurements on the diffuse scattering from MgO are now in progress.

100. The Effect of Target Temperature on the Wavelengths of Soft X-Rays from Metals. PAUL MCCORKLE AND CHARLES B. BAZZONI, *University of Pennsylvania.*—Chalklin reported a small change in the wavelengths of soft x-rays from Ta and W with change of target temperature. We have repeated this work and have extended it to other metals. In order to eliminate some possible sources of error, a camera shutter was designed so that the spectra from hot and cold targets could be photographed on the same plate. No changes were made in cathode, anode, or camera during the entire exposure. The target was heated by electron emission and the temperature was increased from about 200°C to 900°C. A water-cooled target support prevented thermal expansion. Since the two spectra were on the same plate, a shift of 0.2A could have been detected by inspection. No such shift was found for Ta, W, Mo or Ft.

101. Ruled Grating Measurements of X-Ray Wavelengths. J. A. BEARDEN, *Johns Hopkins University.*—A plane grating ruled with 100 lines per mm and 75 mm long has been used in a double crystal ionization spectrometer for measuring the wavelength of the copper $K\alpha_1$ line. The ruled grating was placed between the two "perfect" calcite crystals which were in the (I+I) position. This arrangement places the reflected and diffracted beams in the (I−I) position and the direct $K\alpha_1$ line in the (I+I). Thus the two most important angular measurements were made with very narrow lines. The diffracted α_1 and α_2 lines were 14″ wide at half maximum, and were separated about 45″. The correction for the overlapping of the lines amounted to about 0.2″. Four carefully calibrated microscopes read the precision circle. Since two lines, ten minutes apart, were read in each microscope, eight angular readings were obtained for each individual setting of the circle. Different parts of the circle were used in order to eliminate any effects due to possible erratic rulings on the circle. The average of all the results gave $\lambda=1.5406$A which is 0.253 percent greater than the best crystal measurements. The average of the photographic ruled grating measurements of the author gives 0.247 percent when compared to the same crystal values.

102. Comments on the Coster-Kronig Theory of a New Type of Auger Effect. F. R. HIRSH, JR. AND F. K. RICHTMYER, *Cornell University.*—Coster and Kronig's theory (Physica **2**, 13 (1935)) of the origin of certain L series satellites, by a new type of Auger effect, accounts for their presence by an ionization of the $M_{IV,V}$ shell caused by the radiationless transition $L_{III}\rightarrow L_I$. The atom is then doubly ionized, with $M_{IV,V}$ and L_{III} electrons lacking. Satellites result from a subsequent single electron transition. According to this theory, ionization of the $M_{IV,V}$ shell by the radiationless transition $L_{III}\rightarrow L_I$ should cease at $Z=50$. Experimentally it has been shown that the satellites of $L\alpha_1$, $(L_{III}M_V)$, and the satellites of $L\beta_2$, $(L_{III}N_V)$, extend to $Z=53$ *and then cease.* One might similarly account for the satellites of $L\beta_1$, $(L_{II}M_{IV})$, by

assuming $M_{IV,V}$ ionization to be caused by the radiationless transition $L_{II} \rightarrow L_I$. Coster and Kronig mention that this Auger ionization is possible below $Z=40$ but is impossible above. Coster has however shown that the $L\beta_1$ satellites exend from $Z=29$ to $Z=51$. A study of the intensities of these satellites over their entire range is needed to decide whether the Coster-Kronig theory applies. The Coster-Kronig theory fails to account for the satellites of $L\gamma_1$, $(L_{II}N_{IV})$. It also cannot account for the satellites of $L\gamma_{2,3}$, $(L_IN_{II,III})$. A radiationless transition is impossible in this case.

103. The Auger Effect for Au (79) and the Origin of Certain *L*-Satellites in X-Ray Spectra. E. RAMBERG AND F. K. RICHTMYER,[1] *Cornell University.*—Calculations of Auger transition probabilities reported at the New York meeting have been extended considerably and make possible a more detailed comparison between predicted and observed natural energy level widths. The Auger effect is found to explain the main features of the apparently anomalous variation of the natural widths with the total and azimuthal quantum numbers of the states considered. Furthermore results are given of roughly quantitative calculations of the positions and relative intensities of the $L\alpha$ and $L\beta_2$ satellites of gold on the basis of the hypothesis for their origin recently advanced by Coster and Kronig.

[1] Grateful acknowledgment is made to the American Philosophical Society of a grant-in-aid of this research. F. K. R.

104. X-Ray Line Widths: Correction for Finite Resolving Power of Crystals. LYMAN G. PARRATT, National Research Fellow, AND LLOYD P. SMITH, *Cornell University.*—A study of the widths of several x-ray lines using 14 different pairs of crystals on a two-crystal spectrometer leads to the following conclusions: (1) The width of the $(1, -1)$ curve is *not* an adequate criterion for the resolving power of the crystals. (2) The uncertainties of the crystal contributions depend upon the magnitude of the width of the parallel position curve as well as upon the ratio of the widths of the curves in the parallel and anti-parallel positions. (3) Etching a given pair of crystals may or may not increase the resolving power. (4) The shapes of the single calcite crystal diffraction patterns vary for a given wavelength as indicated by different $(1, -1)$ curve shapes. (5) The different measured degrees of asymmetry of the Ti $K\alpha_1$ line in various orders of reflection indicate that the single crystal patterns of calcite are asymmetrical as predicted by theory. (6) A correlation exists between percent reflection and effective resolving power of crystals having the same $(1, -1)$ widths. (7) A correction formula for obtaining a true x-ray line width may be applied for crystals of high percent reflections in first and second orders providing the ratio of widths $(n, -n)/(n, +n)$ is not greater than about 0.2 for Mo $K\alpha_1$ or 0.1 for Ti $K\alpha_1$.

105. Ionization of Liquids by X-Rays. LAURISTON S. TAYLOR AND FRED L. MOHLER, *National Bureau of Standards.*—Continuing studies reported last year,[1] measurements have been made on the ionization of carbon bisulphide, ligroin, tetrahydronapthalene and various mixtures of the three. To minimize absorption and scattering corrections the ionization chamber consisted of parallel grids of fine aluminum wires separated by fused quartz disks having a 2-cm hole in the center. The ionization current extrapolated to infinite field was proportional to the grid separations in the range 0.5 to 2.5 mm. Precise determination of effective field strengths was complicated by the presence of space charge or dielectric absorption in the liquid. This charge builds up slowly, not reaching a steady value for many minutes, at least, after application of the field. The magnitude of the difference between the applied and effective field is obtained in two ways—(1) by the difference between the initial ion current at zero time and the final steady state current, and (2) by direct measurement of the residual potential difference between the grids after the applied field is removed. After exposure to strong x-rays, the residual potential amounted to the order of 700 volts when the applied field had been 60 kv/cm.

[1] F. L. Mohler and L. S. Taylor, Bur. Standards J. Research **13**, 659 (1934).

106. A Simple Device for Producing Very Small Unidirectional Currents. G. FAILLA, *Memorial Hospital.*—For the measurement of ionization currents a null method is most desirable. This, however, necessitates the production of a "balancing" current of the same magnitude as the unknown current by such means as will permit its evaluation from simple measurements of related quantities. The device consists of a rotating condenser (simply a small insulated metal cylinder) with an excentric pin which makes contact first with a source of potential and then with the ionization chamber producing the current to be balanced. Other conditions remaining constant, the unidirectional current thus produced is proportional, respectively, to the applied voltage and to the speed. The device has been used in conjunction with an FP–54 tube with floating grid and no trouble has been encountered from the intermittent contacts even at low speeds (250 r.p.m.). Readings are easily reproducible. This scheme makes possible the construction of simple and reliable integrating dosimeters for x-rays and ultraviolet light. For this purpose the applied voltage is maintained constant (standard cell) and the speed is varied according to the variations in the intensity of radiation. The total number of revolutions of the condenser is proportional to the dose.

107. A Study of the Crystal Structure of Heat-Treated Tungsten Filaments. R. P. BIEN, *Massachusetts Institute of Technology.*—Straight tungsten filaments have been examined after various heat treatments. Microphotographs of the cross sections and longitudinal sections were made showing the crystal sizes, while x-ray and goniometer measurements were made to show crystal orientation and surface facets. Well aged tungsten filaments all showed very large crystals extending across the entire diameter of the filament. Their lengths varied from two or three cm down to about a tenth cm. This result applied to filaments flashed for a short time at 3100°K and higher, or aged some hours at 2600°K without higher temperature treatment. Optical reflections from well aged 10 mil filaments showed distinct facets when viewed with light at normal incidence perpendicular to the axis of the filament. The predominant reflecting surfaces seem to be the (110) and (211) planes of a crystal oriented with a (110) plane normal to the filament axis. The fact that all Richardson plots so far reported on well aged filaments are perfectly straight lines would indicate that either the work functions of these two surfaces in presence of a strong field are identical, or emission from the (211) planes is so much greater than that from the (110) planes that the latter contribution may be neglected over the observed temperature range.

108. Thermionic Emission from Tungsten with Weak Accelerating Fields. W. B. NOTTINGHAM, *Massachusetts Institute of Technology.*—The thermionic emission from a well aged 3 mil tungsten filament of the G.E. 218 type has been studied as a function of the temperature, over the range 1218°K to 1973°K, and the surface field for values between zero and 64,000 volts per cm. For fields greater than 2000 volts per cm, the observed currents when plotted as log I *vs.* $V^{\frac{1}{2}}/T$ (where V=voltage and T=temperature) are accurately represented by the straight line given by the Schottky mirror image theory. A "zero field" Richardson plot obtained by extrapolating the mirror image lines to zero, yielded an $A=60$ amp. per cm^2 per degree^2 and $b_0=52{,}400°$ in exact agreement with Dushman's values. The true values of emission current at zero field were less than those obtained by extrapolation by 53 percent at 1218°K and 34 percent at 1848°K. Space charge effects definitely distort the results at zero field for temperatures above 1840°K. The surface excess theory of Tonks would suggest that a decrease of 25 to 30 percent should be expected, but this theory cannot account for the above temperature effect. Bien's work on the crystal structure of tungsten shows promise of explaining this if there is a difference in work function of 0.5 to 1.0 volt between the 110 and the 211 facets giving rise to local contact potential fields between facets.

109. Dependence on Applied Field of Thermionic Constants for Thoriated Tungsten. A. ROSE, *Cornell University.* (*Introduced by L. P. Smith.*)—Data are presented for the variation of slope of Richardson plot with applied field, for stages of activation ranging from a flashed surface to maximum activity. An analysis is made of the variation of slope of Richardson plot in terms of a square array patch theory. The size of patch remains roughly constant at 3×10^{-4} cm during activation. The contact potential between patches increases from 0.8 volt for low activity to 1.4 volts near 0.5 monatomic layer and decreases to 0.4 volt for maximum activity. Analysis of data for a thoriated tungsten surface, bombarded and contaminated with alkali atoms, shows an increase in contact potential difference between patches to 2.4 volts. Insofar as the intercept may be related to the change in slope, they are proportional, the constant of proportionality not changing seriously with state of activation.

110. Sputtering of Thorium and Barium from Tungsten. L. R. KOLLER, *General Electric Company.*—Measurements have been made of the sputtering of thorium from tungsten in neon, argon and mercury at pressures of the order of 1 mm. Thoriated filaments were bombarded with ions of known velocity, and surface conditions were determined by thermionic emission measurements. Values were obtained for the number of ions required to remove an atom of thorium from the surface of cold tungsten, at ion velocities between 25 and 70 volts. For 40 volt ions the values were:

9×10^2 ions per atom for neon
6×10^3 " " " " mercury
2×10^6 " " " " argon.

Measurements were also made of the sputtering of barium from tungsten. Sputtering was observed for ions of as low velocity as 12 volts. At 18 volts in neon the value was 3×10^2 ions per atom. Relative values for sputtering, as a function of voltage, were also determined for an oxide coated cathode. A method is suggested for determining the cathode fall by means of the rate of sputtering.

111. The Velocity Distribution of Electrons in Gas Discharge Problems. PHILIP M. MORSE, W. P. ALLIS AND E. S. LAMAR, *Massachusetts Institute of Technology.*—The method used by Langevin and Lorentz to determine the behavior of electrons colliding with elastic spheres has been extended to take into account the angle distribution and loss of energy of the electrons scattered from actual atoms. The detailed balancing of momentum and energy results in differential equations giving the dependence of the distribution function on the coordinates and on the components of the velocity. These equations have been solved in two simple cases. One case is that of a homogeneous beam of electrons, of energy ϵ_0, shot into a field-free space, where they lose energy to the gas atoms by elastic collisions. The distribution function depends on z, the distance along the beam measured in mean free paths,

and on t, the average number of collisions an electron has had before its energy decreases from ϵ_0 to ϵ. It is found that the distribution function is not Maxwellian, but depends on a solution of an equation in z and t having the form of the heat equation, which can be solved subject to suitable boundary conditions. These solutions have been tested experimentally, and a quantitative check is obtained. The other case considered is that of the behavior of electrons in a uniform electric field, where the distribution function is independent of position. The field is assumed to be small enough so that the number of inelastic collisions is small compared to the number of elastic ones. The distribution is found to be proportional to $\exp(-\epsilon^2/a^2)$, instead of to $\exp(-\epsilon/c)$, as is the case in the Maxwell distribution, when the electrons are in thermal equilibrium with the gas atoms. The average energy of the electrons, the drift current, the number of ions created, etc., can be computed as a function of the field strength.

112. The Force at the Anchored Cathode Spot. LEWI TONKS, *General Electric Company.*—The force exerted by a cathode spot anchored as a cathode line (C.L.) along a meniscus edge at a Mo surface has been measured in three different ways. The depression of the meniscus edge with increasing current density gave the value 22.6 dynes/amp. for the total average force exerted normal to the Hg surface. An anchor suspended in Hg from a pendulum gave the value 20.2 dynes/amp. for the same force increased by any pressure against the exposed part of the anchor. This was independent of the area of anchor exposed, so that the latter component was negligible at distances greater than 2 mm from the C.L. A torsion pendulum tube containing Hg with a trace of Mg gave 31 dynes/amp. This large value is not understood. All values lie below the 40 dynes amp.$^{-1}$ from Kobel's measurements on an unanchored confined spot. Cathode force measurements establish a numerical relation between electron temperature, T, in the cathode plasma and the fraction of current, f, at the cathode carried by electrons. For 20 dynes/amp. this is $(1-f)T^{\frac{1}{2}} \sim 20/2.74 = 7.3$ so that if $T = 20{,}000°\text{K}$, $f \sim 0.95$.

113. The Photoelectric Threshold of Uranium, Calcium and Thorium Treated with Limited Amounts of Oxygen. H. C. RENTSCHLER AND D. E. HENRY, *Westinghouse Lamp Company.*—At the meeting of the Optical Society, February 23, 1935, we reported a shift in the photoelectric threshold toward the longer wavelength when a surface of pure thorium is allowed to react with a small amount of oxygen. Uranium and calcium are found to possess this same property. The photoelectric work functions for these oxygen treated surfaces agree remarkably well with the thermionic work functions obtained by Dushman (Phys. Rev. **21** (1923)) for activated tungsten filaments containing oxides of these same metals. The amount of oxygen required for best results depends upon the area and thickness of the active coating. The threshold shift is definitely obtained before the interaction with the oxygen is complete. Excessive amounts of oxygen again completely destroy the photoelectric activity in all cases.

114. Stepwise Fluorescence in Mercury Vapor; The 3650 Line. LOUIS A. TURNER, *Princeton University.*—This paper presents modifications of E. Gaviola's theoretical treatment of the experiments of R. W. Wood and of himself on stepwise fluorescence (Phil. Mag. 6 (1928)). No new experimental results are given. They showed that if the intensity of the exciting light of all wavelengths be changed by a factor, f, the intensity of 3650 in fluorescence varies as f^3 and the intensities of many other lines vary as f^2. From this result, with equations for the steady state, one can conclude: (1) That the $^3P_2$ metastable atoms are destroyed principally by collisions rather than by absorption of radiation; (2) that the concentration of $^3P_0$ metastable atoms is probably proportional to that of $^3P_1$ atoms; (3) that the $^3S_1$ atoms can be produced by absorption of both 4358 and 4047 to a comparable extent. Wood found that the addition of nitrogen produces either a decrease or an increase of the intensity of the 3650 line according to whether 4047 and 4358 are present in the exciting light or not. This result can be accounted for on the plausible hypothesis that collisions with nitrogen molecules effect interchanges of atoms among the $^3D_3$, $^3D_2$ and $^3D_1$ states as well as decrease the concentration of the $^3P_2$ atoms. The intensity of the 3650 line at the higher pressures of nitrogen is greater than Gaviola's theory predicts. This additional effect accounts for the discrepancy.

115. Quenching of Cadmium Resonance Radiation (3261) by N_2, CO and CH_4. HARRY C. LIPSON AND ALLAN C. G. MITCHELL, *New York University.*—The quenching of Cd resonance radiation (3261) has been extended to include the gases CO, N_2 and CH_4. The method used is the same as that previously described.[1] On plotting the reciprocal of the quenching (τZ_Q) against the pressure of the foreign gas a straight line results for all gases measured to date. The values of $\sigma^2_Q \times 10^{16}$, computed in the usual manner from the curves, are: H_2, 0.67; CO, 0.14; N_2, 0.02; CH_4, 0.012. The energy difference between the excited (5^3P_1) and the metastable (5^3P_0) states is 0.07 volt, a quantity of the order of magnitude of the thermal kinetic energy of the molecules at the temperature used (210°C). It seems probable that the process in the case of N_2 and CH_4 is a transfer of the atoms to the metastable state with a resulting increase in the translational energy of the N_2 or CH_4 molecule. In the case of CO the Cd atom is probably returned to the normal state, the excess energy going into vibrational energy of the CO molecule. In the case of hydrogen there are two possibilities: (1) the formation of CdH+H and (2) a process similar to that in CO.

[1] H. C. Lipson and A. C. G. Mitchell, Abstract New York Meeting, 1935.

116. The Crystal Structure of Ammonium Chlorobromoiodide. R. C. L. MOONEY, *Newcomb College, Tulane University.*—The crystal structure of ammonium chlorobromoiodide has been determined by x-ray methods, and accurate data concerning the complex anion group obtained. The crystal is orthorhombic. The unit cell, containing four molecules, has the following dimensions: $a=6.14$A; $b=8.58$A; $c=10.03$A. The space group is $Pmcn(V_h^{16})$. The halogen positions were found by intensity considerations, while the ammonium positions were located by means of a two-dimensional Fourier series calculation of electron density. The parameters, which give good agreement between observed intensities and calculated structure amplitudes, are as follows:

	$2\pi x$	$2\pi y$	$2\pi z$
NH_4	90°	10°	131°
Cl	90°	135°	65°
I	90°	202°	135°
Br	90°	265°	203°

Thus the atoms all lie in planes which are perpendicular to the x-axis and separated by a distance $a/2$. The halogen atoms are associated in a strictly linear group, the iodine lying at the center. The distance between the iodine and bromine atoms in a group agrees closely with the sum of the atomic radii of iodine and bromine as found in I_2 and Br_2 from band spectra. The separation between I and Cl is slightly larger than the value given for the ICl molecule. The ammonium atom is coordinated with four chlorines at a distance of 3.34A; four bromines at a distance of 3.63A; and two iodines at a distance of 3.79A.

117. Fourier Analyses of X-ray Patterns of Phosphorus. N. S. GINGRICH AND RALPH HULTGREN, *Massachusetts Institute of Technology.*—A Fourier analysis of the x-ray powder patterns of four samples of phosphorus has been made. Black crystalline, black "amorphous," red crystalline, and red "amorphous" samples of phosphorus were used, and diffraction patterns were obtained by means of Mo $K\alpha$ x-rays, monochromatized by reflection from a rocksalt crystal. From these patterns, the distribution of atoms about any one atom was determined with the aid of a Coradi analyzer. In all four cases, the number of nearest neighbors is three, at a distance of 2.28A, in agreement with the accepted radius of 1.10A for the phosphorus atom, and the threefold coordination expected in a covalent structure. The number of next nearest neighbors is approximately twelve and they are at about 3.6A in all four cases. The number and positions of more remote neighbors are less definite, but they appear to be different for the various samples. In the case of crystalline black phosphorus, the atomic distribution curve has led to a complete structure determination.

118. The Crystal Structure of Black Phosphorus. RALPH HULTGREN AND B. E. WARREN, *Massachusetts Institute of Technology.*—The rhombohedral structure of black phosphorus reported in the literature by Linck and Jung gives improbable interatomic distances. The set of lines they report does not agree with the lines we obtained from five different samples. These lines cannot be fitted to a lattice of high symmetry. Preferred orientation of some of the lines indicates a layer structure, agreeing with the graphite-like properties of the material. Using this fact and the results of the Fourier analysis reported earlier, we were able to derive a structure which has a side centered orthorhombic cell of the following dimensions: $a_0=3.31$A, $b_0=4.38$A and $c_0=10.50$A. The first 42 lines of the cell fit the accurately determined interplanar spacings. The cell has 8 atoms, which gives a calculated density of 2.69 g/cc in place of the experimental 2.70 g/cc. The space group is $V_h^{18}-Bmab$ and the two parameters of the eight atomic positions occupied can be determined from line intensities, giving excellent agreement. The structure consists of double layers 5.25A apart. Each atom is surrounded by three neighbors at 2.18A with bond angles slightly larger than in the arsenic structure. The latter structure is not quite so dense, which is probably the reason the high pressure form of phosphorus prefers the black phosphorus structure.

119. The X-ray Analysis of Amorphous Rubber. G. L. SIMARD AND B. E. WARREN. *Massachusetts Institute of Technology.*—The x-ray scattering curve for unstretched rubber is obtained with Cu $K\alpha$ and Mo $K\alpha$ radiation. To eliminate background correction a vacuum camera is used, and the radiation is monochromatized by NaCl reflection. A typical amorphous pattern is obtained showing three distinct peaks. By the usual method of Fourier analysis, a distribution curve is obtained giving the average number of carbon atoms to be found at any distance from a given carbon atom. The first peak in the distribution curve occurs at 1.5A and contains 2.0 carbon atoms. The second peak is at 2.6A and has an area corresponding to about 3.5 carbon atoms. As the peak is not sharply defined on the outer side, this number represents second nearest neighbors and others beyond. The results are in good agreement with the usual chain molecule. The strong inner peak observed in the diffraction patterns of unstretched rubber is due to a slight excess distribution at about 5.0A.

120. The X-ray Analysis of Vitreous B_2O_3. B. E. WARREN AND O. MORNINGSTAR, *Massachusetts Institute of Technology.*—The x-ray scattering curve for vitreous B_2O_3 is obtained in a vacuum camera with Cu $K\alpha$ and Mo $K\alpha$ radiation monochromatized by crystal reflection. The sample was in the form of a cylindrical rod. The glass gives a typical amorphous pattern showing four distinct peaks. The method of Fourier analysis is readily extended to the case of a material containing more than one kind

of atom, by setting each atomic scattering factor $f_m = Z_m f_0$ where Z is the atomic number and f_0 is a weighted average scattering factor per electron. The distribution curve which is obtained shows strong peaks at 1.4A and 2.38A. The first is due to the B−O distance and the second to the O−O distance. Both the distances and the areas under the peaks indicate a triangular coordination with each boron bonded to three oxygens and each oxygen to two borons.

121. Slip, Twinning and Cleavage in Silicon Ferrite (4.17 percent Si). CHARLES S. BARRETT, *Carnegie Institute of Technology.*—The crystallography of the deformation process was determined in five single crystals cut from sheets of commercial silicon iron containing 4.17 percent Si. Each crystal was mounted and polished and its orientation determined by stereographic projection of back reflection Laue photographs. Each crystal used was free from distortion and lineage; its orientation was determined from 50 or 100 sharp spots with an accuracy of ±0.5°. Deformation markings on the polished surface were photographed at 100 diameters and plotted on the projection. As expected from previous results, repeated bending causes cleavage on cube planes, {100}, and hammer blows cause twinning (Neumann bands) on icositetrahedral planes, {112}. Slip produced by slow inhomogeneous deformation at 20°C, however, does not occur by the mechanisms proposed by Gough, or Taylor, or Fahrenhorst and Schmid for α-iron; the slip lines are generally straight instead of wavy as in α-iron, and slip occurs *only* on rhombic dodecahedral planes, {110}. These are preliminary results in a general study by the Metals Research Laboratory of the effect of alloy composition and temperature on the deformation process in iron.

122. New Lines in the *K* Series Spectrum of Tungsten. J. C. HUDSON AND H. G. VOGT, *Harvard University,* AND A. H. ARMSTRONG, *Wesllesley College.*—A re-examination of the K series x-ray spectrum of tungsten has been carried out with a high dispersion spectrograph in which the dispersion is 0.5 X.U. per mm. The Bragg focusing arrangement is used with a distance from slit to crystal of 615 cm. The crystal is oscillated through 30 minutes of arc by means of a cam so that the entire K spectrum is secured with one exposure. The regular diagram lines appear on the photographic plate though the delta doublet is not separated appearing as a single line. The separation of δ and γ_1 is 0.96 X.U. and lying between these two lines is a very faint new line of wavelength 178.6 X.U. which apparently results from a $N_{IV,V}-K$ transition. Between γ_2 and β_1 are two faint lines of wavelength 179.9 X.U. and 182.8 X.U., respectively. The first cannot be assigned to any transition in tungsten but agrees well with the $K\alpha_1$ line of gold. The second line agrees well with the $M_{IV}-K$ transition in tungsten. Both of the new tungsten lines are very faint compared to the regular diagram lines.

SATURDAY AFTERNOON AT 2:00 O'CLOCK

National Academy of Sciences

Lecture Hall

123. Interaction of Nuclear Particles. LLOYD A. YOUNG, *Carnegie Institute of Technology.*—Heisenberg's assumption concerning nuclear binding was that the main effect arose from a proton-neutron attraction. Majorana, in an important contribution, showed that this attractive force could not be like classical forces but had to be of an exchange nature. The amended theory predicts certain nuclear properties in a qualitative way but is unsatisfactory in others. First, the magnitude of the Majorana proton-neutron interaction, as determined from mass-defects of heavy nuclei, is too large to explain the small mass-defect of the deuton. Second, the theory predicts too large a value for the ratio Z/A. Finally, a theory based on proton-neutron interactions alone (plus eventually Coulomb forces) cannot explain the striking odd-and-even number properties of nuclei. In the present work the effects of proton-proton and neutron-neutron forces of the Majorana type are considered. We are led to assume that every nuclear particle interacts with every other nuclear particle in the Majorana sense. The new attack resolves the above difficulties satisfactorily, giving values for the parameters of the interaction, mass-defects, nuclear radii, etc. Finally it gives a very simple explanation of odd-and-even nuclear properties.

124. Neutron-Proton Interaction and the Binding Energies of the Hydrogen and Helium Isotopes. EUGENE FEENBERG, *Harvard University.*—In the present state of nuclear theory it is reasonable to assume, for particles bound in the same nucleus, that the neutron-proton interaction operator can be represented fairly well by a potential function $J(r)$. Taking $J(r)$ to have the form $Ae^{-\alpha r^2}$, which is well adapted to the discussion of the three and four body problems, A and α have been determined to fit the binding energies of the deuteron and the alpha-particle. The results are roughly $A = 170mc^2$, $1/\alpha^{\frac{1}{2}} = 1.3 \times 10^{-13}$ cm, with both the Wigner and Majorana theories. The computed binding energy of H^3 has the value $12.7mc^2$ (Wigner) or $11.2mc^2$ (Majorana), not very far below the experimental value of $16.0 \pm 1.7(?)mc^2$. The two theories appear to be about equally good. It may be that also in the case of free particles the interaction operator can be represented by a potential $J'(r)$. Because the conditions of binding and of scattering are so different there is no reason to expect J and J' to be identical. The inequalities $J' < J$ and $\partial J'/\partial W < 0$ (W—kinetic energy) should hold if some part of the potential results from a polarization of each particle in the field of the other or from a high frequency exchange process such as that suggested by

Heisenberg. For slow neutrons a thirty-percent *decrease* in the magnitude of the interaction in going from binding to free particles yields an *increase* in the scattering cross section against protons of several hundred percent over the value given by J. This larger value is required by recent measurements. The rapid fall of the experimental cross section with increasing W requires that J' decrease steadily as W is made larger.

125. Energy Levels of Light Nuclei. GUIDO BECK, *University of Kansas.* (*Introduced by H. W. Webb.*)—The theoretical analysis of the experiments on the anomalous scattering of alpha-particles which recently has been given by P. Wenzel and L. H. Horsley shows that it is possible to determine the quantum numbers of the virtual energy levels of light nuclei. The virtual energy levels investigated fit nicely in a simple picture for the structure of light nuclei which can be schematically represented by a potential hole of variable depth. This picture holds if one assumes that—at least in light nuclei—every pair of neutrons and protons is bound in an intranuclear alpha-particle. This view is strongly supported by the mass defects. No unambiguous conclusions can so far be reached on the nuclear spins but it can be shown that several levels of slightly different energy and of low spin values play a role in the structure of light nuclei.

126. The Interaction Between a Neutron and a Proton. L. H. THOMAS, *Ohio State University.*—It has been suggested (E. Wigner, Zeits. f. Physik **83**, 253 (1933)) that the interaction between a neutron and a proton can be regarded as described by a singularity of the wave function in their configuration space where their positions coincide, of such a nature as to give the observed mass defect of H^2. A function has been found which makes the expression for the energy in the corresponding variation problem for H^3 arbitrarily large and negative, provided that there is no compensating repulsion between the two neutrons. Subject to this provision, the above suggestion seems to be untenable; in fact a lower limit to the distance below which a neutron and a proton are effectively in interaction may be deduced.

127. A Nuclear Model. WILLIAM V. HOUSTON, *California Institute of Technology.*—If a nucleus is treated as composed of alpha-particles, protons and neutrons, the forces between the particles can be crudely approximated as attractions proportional to the distance. This approximation has the great advantage of giving a problem which is soluble as an n-body problem. By assuming force constants of a reasonable order of magnitude it is possible to account for the general trends of nuclear binding energies. The instability of Be^8 and the stability of C^{12} composed of two and three alpha-particles, respectively, is understandable. A limitation on the number of neutrons which are bound to a given number of alpha-particles can be imposed from energetic considerations by the application of the Pauli exclusion principle to the neutrons among themselves. Alpha-particle radioactivity does not appear in the model because only attractive forces are considered. This property could be added by some sort of repulsion between the alpha-particles or some sort of exclusion principle. The model gives the correct magnitude for the excited levels of C^{12} and O^{16}, but does not give the large number of close levels observed in the radioactive elements. These can perhaps be included by slight modifications of the forces.

128. The Electronic Structure of Diamond. GEORGE E. KIMBALL, National Research Fellow, *Massachusetts Institute of Technology.*—The quantum-mechanical methods of Wigner, Seitz and Slater have been applied to the structure of the diamond. The lattice eigenfunctions were approximated by linear combinations of $2s$ and $2p$ functions of carbon. It is found that the $2s$ level splits into two energy bands in the lattice. One of these bands keeps its s-like character as the interatomic distance is decreased. Its energy shows a strong minimum in the neighborhood of the observed carbon-carbon distance. The other band shows a slight maximum in energy and then a minimum, again near the observed carbon-carbon distance. The corresponding eigenfunctions lose their s characteristics and become p-like. The $2p$ level splits into six bands, two following the course of the $2s$ bands, the other four being repulsive. The number of available electrons is just sufficient to fill the two $2s$ bands and the two low $2p$ bands. The large gap in energy between the highest filled band and the lowest empty level explains the absence of electrical conductivity.

129. The Electronic Structure of Copper. HARRY M. KRUTTER, *Massachusetts Institute of Technology.* (*Introduced by J. C. Slater.*)—The method of Wigner, Seitz and Slater has been applied to the calculation of the energy levels and wave functions of the electrons in the face-centered copper lattice, assuming a spherically symmetric field about each atom, and making the functions continuous at the midpoints between nearest neighbors. As a first approximation the Cu^+ potential field of Hartree was used for the s, p and f states. A correction for the $4s$ electron was used in the study of the $3d$ electrons. Calculations of the energy bands on this basis show a strong overlapping of the $3d$ band with the $4s$ band. The minimum of the $4s$ energy band comes approximately at the correct interatomic distance for copper. Results of the calculation of energy as a function of momentum, which can only be solved simply in the 100, 110 and 111 directions, show that the eleven electrons $3d^{10}4s$ fall into six bands, five of which are filled, leaving one electron in the unfilled band, accounting for the conductivity of copper. This electron cannot be said to be either an s or d electron but is built up of s, p and d wave functions. In the 100 direction this electron behaves roughly as a free electron.

130. On the Reduction of Space Groups. FREDERICK SEITZ, *Princeton University.*—The connection between group theory and quantum mechanics has proved to be of considerable service in the development of the theory of the solid state, and in this work the range of reduced groups has been extended to include the 230 space groups. Though

it has been found practical to develop no more than a scheme by means of which the reduction may be carried through, this scheme is entirely convenient and may be applied to any given group. Among a number of definite applications of these results, one of the most outstanding, at present, is concerned with an investigation of the discontinuities of the energy of the electron waves in metals when the energy is regarded as a function of the wave number vector. These discontinuities appear at the so-called Brillouin zones, and are connected with the partial removal of a degeneracy which obtains for waves going with vectors not on a zone. The results for a body-centered lattice of the type met with in simple metals are being determined at present.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member one only of these will be assigned a place on the regular program while the others will be placed in a supplementary program to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for only at the session indicated.

131. Ionization Balance of the Atmosphere Near the Earth's Surface. G. R. WAIT, *Carnegie Institution of Washington, Department of Terrestrial Magnetism.*—The number of small, molecular ions in a gas depends upon the ratio of rate of production to that of destruction. Small-ion destruction-rate in the lower layers of the atmosphere is due principally to the presence of larger ions and uncharged particles, the number of which varies considerably and systematically through the day. The rate of small-ion production in the lower atmosphere also undergoes large and systematic variations through the day, as shown in the preceding paper. This observed rate of production provides a check on any calculated rate of production, based on the number of small ions in the atmosphere and the number of larger particles present acting to destroy them. Observations in Washington, D. C., during the past year have provided data for making comparisons between calculated and observed rates of production. It is found, contrary to prevailing opinion, that the large or Langevin ion does not play a predominant role as a remover of small ions. The intermediate ion, having a mobility of about 0.07 cm per sec. per volt per cm, due to its much larger combination-coefficient, plays an equally important part in the removal of small ions from the lower atmosphere.

(To be called for immediately following paper No. 8.)

132. Effect of Cosmic-Ray Energy Upon Stoss Production. W. F. G. SWANN AND D. B. COWIE, *Bartol Research Foundation.*—The fact that the intensity of Stoss and shower production increases with altitude much more rapidly than does the cosmic radiation intensity itself leads one of us to the view that the intensity of Stoss production was a rapidly increasing function of the energy of the primary cosmic rays. If such is the case, Stoss production per unit intensity of primary, by primary rays which are limited to a vertical direction, should be much larger than the corresponding quantity for primary rays limited to directions in the neighborhood of 45°, since the latter rays have travelled a much greater thickness of atmosphere. To test this conclusion we set up an apparatus comprised of a one-inch thick iron sphere suitably arranged as a Stoss measuring ionization chamber. One set of counters was placed vertically above and another was placed vertically below the center, and the two were used as a double coincidence set. Coincidences between this counter discharge and Stösse produced serve to indicate which Stösse were produced by the vertical rays determined by the counter system. An exactly similar pair of counters arranged at 45° to the vertical gave the information for this direction also. The experiments show that while over a period of 48 hours the number of counts obtained by the vertical and 45° counters was in the ratio of 2.7 to 1, the corresponding number of Stösse (involving more than 1.5×10^6 ions) was in the ratio of 12 to 1, which result confirms the conclusion cited above.

(To be called for immediately following paper No. 83.)

133. Observations on the Townsend Discharge in Neon. EUGENE W. PIKE, *Scott Paper Co., Chester, Pa.*—The potential V_T across a self-maintaining Townsend discharge in neon is sensitive to illumination of the discharge with light from a positive column discharge in neon. The relationship of this change in $V_T(\Delta V_T)$ to gas pressure, gas purity, and electrode geometry has been investigated in detail. Although ΔV_T is enormously sensitive to traces of foreign gases in the neon, in the purest possible neon it is very small ($\approx$1 volt), negative, and practically independent of pressure and electrode geometry. A tentative interpretation in terms of atomic processes yields the following major information:

(a) The *motion* of neon resonance radiation in neon at a few mm Hg pressure is essentially in straight lines.

(b) Slow neon metastable atoms radiate their excitation energy on striking a metal surface; this radiation is emitted isotropically, including into the metal.

The first conclusion is supported by the observation of Langmuir and others that the resonance lines from a positive column discharge in neon were transmitted

rectilinearly for considerable distances in unexcited neon, and finds a tentative explanation in the theory of the excited neon molecule.

(To be called for immediately following paper No. 90.)

134. Refraction of the Copper $K\beta$ Line by a Diamond Prism. J. A. BEARDEN, *Johns Hopkins University.*— Precision measurements of the index of refraction of x-rays may be used as a means of determining x-ray wavelengths. Since the method of correcting for the electronic binding is unsatisfactory in some details it is best to use a prism of very low atomic number in which the effect will be very small. A diamond prism fulfills all requirements better than any other substance. Photographic refraction measurements of the copper $K\beta$ line have been made using a 90 degree edge of a diamond block 9 mm×9 mm ×3 mm. Two surfaces were polished optically flat and a very perfect edge was obtained. However, absorption was so low that it was not necessary to allow any part of the x-ray beam to strike the edge of the prism. The gold faced slits were 0.003 mm wide and were 430 mm apart. The prism to plate distance was 1908 mm. The exposure time was varied from 3 to 12 hours. The result from 25 of the best plates gives $\delta=[9.224\pm.005]\times10^{-6}$. This gives λ Cu $K\beta=1.3924$A which is 0.26 percent greater than the best crystal values. Thus the refraction measurements are in complete accord with the ruled grating results.

(To be called for immediately following paper No. 106.)